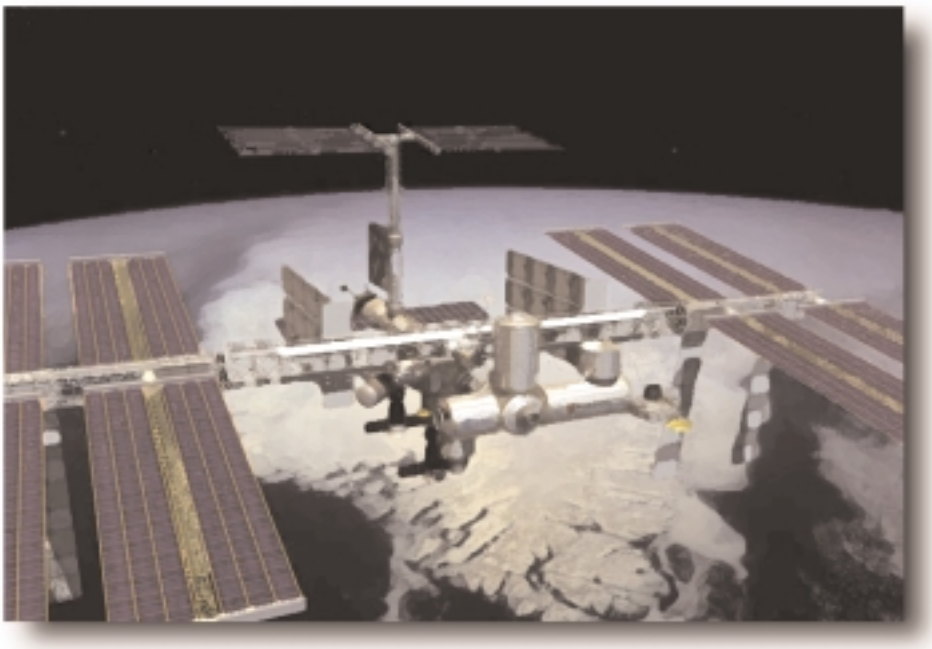
KPMG

NASA: COMMERCE AND THE INTERNATIONAL SPACE STATION



NOVEMBER, 1999

EXECUTIVE SUMMARY

This report was developed by KPMG LLP (KPMG), under contract to NASA and with support from an independent team of industry executives, to examine the potential for commercial utilization of the U.S. portion of the International Space Station (ISS). KPMG was tasked to provide a literature review of existing market research on ISS commercial utilization, and to identify a set of non-exclusive "Pathfinder" projects which could act as enablers to accelerate the process of commercializing the ISS. The Commercial Space Act legislation, which formed the basis for our effort, originally had requested that a market study be conducted. During the planning process for this study however, it became clear that the future commercial markets for the ISS are still too premature and any market study would be wholly speculative. In the larger sense, markets for the ISS must be nurtured, rather than studied.

The lifecycle costs for the ISS have been estimated at over $94 billion[1], and the annual operating and utilization costs are currently projected to be in the neighborhood of $1.3 billion. It should be noted that the ISS lifecycle cost estimates include funding requirements for the design, launch, assembly and 10-years of operational support. These estimates cover a period from 1985 until 2012. The station-related transportation component of the lifecycle cost has been estimated at $52.3 billion. NASA's current estimate for ISS development is between $24 and $26 billion. NASA has expressed a willingness to use alternate private transportation providers where safe and cost effective, if and when they emerge. NASA's allocation of 30% of ISS resources for commercial users is understandable, given the agency's long-standing position that there is utility in space-based R&D.

NASA has defined the meaning of its 30% allocation of ISS resources for commercial use in the following way:

> "The NASA Space Station Utilization Board has formally established a policy to allocate 30% of the US share of internal pressurized user accommodations and 25% of the external attached user accommodations on the ISS to commercial development. NASA has expressed a willingness to expand this allocation as commercial demand increases, provided that such demand does not require NASA subsidization. User "accommodations" are defined in the international MOUs as the International Standard Payload Rack (ISPR) sites, located inside the pressurized laboratories, and the attached payload accommodation sites located outside on the ISS transverse boom, as well as attached user sites located on the Japanese Experiment Module (JEM) Exposed Facility (EF).
>
> In total, at assembly complete, this currently represents:
> (27 ISPR sites) x (.30 allocation) = 8 internal commercial sites

[1] Space Station: Estimated Total U.S. Funding Requirements (Letter Report, 06/12/95, GAO/NSIAD-95-163)

(29 attached sites) x (.25 allocation) = 7 external commercial sites

These sites will include the commensurate resources necessary to undertake productive payload operations. The international MOUs define user "resources" as power, crewtime, transportation and communications capacity. These resources are also allocated at similar levels; however, payload planning will allow specific users to operate above or below the allocated levels on a scheduled basis. In other words, the resource allocations are very flexible.

As the commercial development program matures, NASA is prepared to increase commercial allocations in response to increases in the ratio of private to public investment. NASA's criteria are clear – commercial enterprises which demonstrate the highest private investment levels and involve products or services offered to non-government markets will advance most quickly in the queue.

Criteria related to safety will always remain paramount."

This level of commercial participation in the ISS would allow NASA to meet the Congressional mandates for commercialization while simultaneously freeing up funds for other critical NASA missions.

Methodology

In conducting our literature review, we used the market segments as defined in the 1994 Commercial Space Transportation Study (CSTS) Report. We included an overview of the top-level ISS-related literature that was published from 1994 to 1999. These market segments included a number of promising commercial opportunities in space unrelated to the ISS that we removed from consideration. The remaining market segments were then examined through currently available literature. These literature reviews are contained in Appendices A and B of this report. The data collection methodology employed by KPMG is provided in Appendix C.

Commercial Space Ventures Advisory Team

KPMG convened the Commercial Space Ventures Advisory Team (CSVAT). This team is comprised of a distinguished panel of experts representing a broad spectrum of expertise: from aerospace executives and financiers to entrepreneurs and state government representatives. The CSVAT met with KPMG three times during the course of this study and provided us with ongoing critical review and feedback on our findings. During these meetings, a better understanding of the larger ISS commercialization issues was developed. Details on the composition of the CSVAT are included in Appendix F of this report.

The Market

To most effectively evaluate the level of commercial interest in the ISS, we first had to develop an

understanding of what the term "commercialization" means and where it fits into the spectrum of possible approaches to ISS utilization. This term has been used as a catchall phrase by both NASA and industry to encompass a number of disparate areas of commercial activity: operation of the ISS by commercial entities; utilization of the ISS by commercial users; and augmentation of the ISS by commercial entities.

Based upon our findings and analysis of the market segments reviewed, it appears that in the near term, the most probable avenues for significant commercialization will not be tied to the research and development capabilities of the ISS. Rather, early commercial participation in the ISS will likely be from non-traditional areas such as entertainment, education and advertising. While this does not in effect utilize the ISS for its core science and technology mission, it will have two positive effects: early commercial revenue generation - which can offset the cost of long-term R&D expenditures through application of this revenue to further commercial development - and increased overall awareness of the ISS program worldwide.

As the perceived value of ISS resources and capabilities increases over time, the magnitude of commercial activity may exceed NASA's current planned 30% allocation of resources. In addition, the eventual price paid by industry to use the ISS may exceed the marginal cost incurred for that use. This could provide a significant commercial contribution towards the annual operating costs of the ISS or for reinvestment in economic development.

Impediments to Commercialization

For almost two decades, NASA has promoted both the Space Shuttle and the ISS as valuable platforms for conducting unique space-based Research and Development (R&D) that would have significant value for US industry and the taxpayers. However, in that time, the level of commercial interest in conducting these missions has been limited at best. The weak interest is understandable, given the barriers to and immaturity of commercial space development that have existed and continue today.

KPMG found, in the course of our research, that a significant number of such impediments must be addressed and resolved by NASA, industry and government if the ISS is to be successfully "commercialized". The most critical impediments we identified can be summarized by the following:

- Uncertainty and magnitude of total price (i.e., transportation, integration, and operations) makes return on investment (ROI) impossible to calculate for potential commercial users;
- The lack of awareness in the non-aerospace community regarding the defining characteristics of the ISS (capabilities, range of potential uses and value) among potential commercial participants

inhibits serious market demand for those characteristics;

- The restrictions in existing law, regulations, and policy which limit commercial payloads on Shuttle limits prospective interest in ISS commercial use;
- The burden of complex rules and procedures associated with accessing the ISS via piloted or non-piloted launch vehicles have deterred potential commercial users because of unacceptable cost and schedule penalties;
- Lack of guaranteed Space Shuttle access on a regular basis to commercial users due to lack of availability of the Space Shuttle on a predictable schedule deters potential industry users that require multiple flights of experiments within a defined time period.

Recommended Actions

KPMG and the CSVAT believe that fundamental changes must be undertaken to mitigate the issues and impediments raised above. These changes encompass the financial, policy, regulatory, technical, and market realms. The most important of these are the following:

- Create a market-oriented price mechanism for commercial usage of ISS resources;
- In concert with commercial users, streamline all procedural elements for using the Space Shuttle and the ISS, without sacrificing acceptable safety considerations;
- Create a proactive culture towards commercial and government collaboration with respect to ISS and Shuttle commercial activity;
- Create an aggressive outreach program to attract private industry users for the unique resources and capabilities of the ISS.

The Independent Asset Manager

It would arguably be more effective to have an independent organization serve as the asset manager and single interface point for all commercial users of the ISS to maximize near-term commercial participation. The entity should be created or selected from the private sector to fulfill this mission. This entity must have the authority to act independently within predefined limits, in conducting the business of the ISS (e.g. allocation of ISS resources, pricing of ISS services, etc.). This organization should be incentivized to ensure a consistently proactive stance towards commercial utilization of the ISS and allow for the growth of a competitive commercial environment in Low Earth Orbit (LEO).
As an example, over time it may be possible for the asset manager to create a revolving fund for ISS maintenance, upgrades, and economic development through a percentage allocation of commercial revenues.

Pathfinders

In collaboration with the CSVAT, KPMG has identified five Pathfinder projects representative of what might be undertaken by industry participants in collaboration with or supported by NASA and Congress. The CSVAT was composed of many direct competitors in the industry, and, as such, we believe it created an atmosphere that was inherently unbiased in selecting the Pathfinders. These projects were selected based in large part upon their potential to increase commercial utilization of the ISS in the next five years. Summaries of the Pathfinder projects are provided in Appendix D.

Conclusion

KPMG and the CSVAT believe that the findings, mitigations, and conclusions provided in this report must be incorporated into policy, as they are fundamental to promoting successful commercialization of the ISS. Government agencies have not been overly effective in the direct development of new commercial markets, nor need they be. However, building commercial markets for the ISS has been identified as an important goal. Hence, the need for an independent organization to facilitate the commercialization effort. While the Pathfinders recommended may help to move the process forward, it must be noted that significant barriers to commercialization of the ISS will remain and must be resolved. Industry, academia and government must continue to work together to reduce these barriers. In doing so, the ISS may be positioned as a significant enabler for the growth of commercial space activities. It should be noted that NASA has taken a proactive approach to the ISS commercialization issue by publishing a Commercial Development Plan in November of 1998.

CSVAT ACKNOWLEDGMENT

KPMG convened an external advisory panel, the Commercial Space Ventures Advisory Team (CSVAT), to review the research findings and provide a cross-industry perspective to the report. The composition of the panel was developed jointly by NASA and KPMG and consisted of representatives from various industries, including: aerospace, venture capital, investment banking, entrepreneurial, state government, pharmaceuticals and Commercial Space Center (CSC) sectors. The members of the CSVAT are as follows:

- Congressman Robert Walker (CSVAT CHAIRMAN), President
  The Wexler Group
- Dr. David Boyle, Director
  Commercial Space Center for Engineering
- Dr. Robert Dean, Vice President Strategic Planning and Business Development
  United Space Alliance
- Mr. Frank DiBello, General Partner
  SpaceVest
- Dr. Robert Z. Gussin, Corporate Vice-President Science and Technology
  Johnson & Johnson
- Dr. Shelley Harrison, CEO and Chairman of the Board
  SPACEHAB Inc.
- Mr. Charles Lauer, Vice President Business Development
  Pioneer Rocketplane
- Mr. Ralph Moslener, Manager Commercialization/International Space Station
  The Boeing Company
- Mr. Jerry Rising, President
  VentureStar LLC
- Mr. Del Schuh, Executive Director
  Aerospace States Association
- Mr. Richard Smithies, Director
  Barclays Capital

We would like to express our gratitude to the members of the CSVAT for their active participation and valuable feedback on the development of this report, their input on the various commercial market sectors.

INTRODUCTION

ISS Becoming Reality

1998 marked the first step in a new era of space development – the launch and in-orbit assembly of the first two elements of the ISS, Zarya and Unity. The ISS is the culmination of decades of planning and design and represents a level of international collaboration unprecedented in the history of space flight. Over the next six years, the ISS will continue to take form, providing industry, academia and governments with the ability to conduct research in an advanced orbital facility with capabilities not currently reproducible on Earth.

The ISS also represents a significant investment in financial terms, a level not seen in a civil space program since the Apollo era. Even with the international program cost-sharing strategy, the U.S. government will continue to shoulder a significant portion of the overall costs of development, assembly and operation of the ISS.

There are several driving forces behind NASA's current effort to "commercialize" the ISS. The 1984 amendment to the NASA Act of 1957 obligates NASA to promote the commercialization of space. More recently, the 1998 Commercial Space Act required that NASA actively seek commercial users for the ISS.

> "...the use of free market principles in operating, servicing, allocating the use of and adding capabilities to the Space Station, and the resulting fullest possible engagement of commercial providers and participation of commercial users will reduce Space Station operational costs for all partners and the Federal Government's share of the United States burden to fund operations."

Meaningful commercial utilization of the ISS will have another positive side effect for NASA. It will ease the Operations and Utilization (O&U) burden NASA must carry, currently projected to be $1.3 billion annually. Successful commercial use of the ISS may further NASA's ability to pursue other critical non-ISS missions.

NASA's stated intention is to allocate 30% or more if unsubsidized demand emerges, of the U.S. portion of the ISS resources for commercial use. It is apparent from the definition of resources that this allocation will be flexible, driven largely by the availability of various resources (crew time, power, rack space etc.) and interest levels of the private sector. Regardless of the metric or combination of metrics that are used to determine the 30% allocation of ISS resources, the intent is clear – NASA desires to provide a commercial space based platform that, if successful, could establish the foundation for a private growth market involving human operations in space.

Assumptions

KPMG developed this report using the following set of framing assumptions:

- U.S. Domestic – Although the ISS is an international partnership, the focus of this report was on the potential for commercialization within the context of the U.S. portions of the facility. As such, we did not examine international opportunities or US/International cooperative efforts for commercial utilization of ISS;

- Commercial-related – While there are many applications for the capabilities of the ISS by government, non-profit, or university user communities, those fell outside the scope of this work;

- ISS-related – The scope of all potential commercial activity in space is expanding, and much of the proposed activity has little or nothing to do with the ISS platform (e.g., hotels in space). We therefore included only ISS-related data.

Definitions

As a result of the rapid growth in commercial activity in space, primarily in telecommunications, there have been growing political and fiscal imperatives within government to transition the majority of the government's space operations to the private sector. This has become apparent in both the civil and military spheres of space. Within the last several years, NASA has initiated the first steps on multiple large-scale programs to privatize key space operations. Much of the current Department of Defense (DoD) long-range planning also relies heavily on the leveraging of commercial communications, launch and imaging services.

Before we may quantify the potential for commercial utilization of ISS, it is important to understand the spectrum of operational approaches between pure government and pure commercial. To maintain consistency within this discussion, we have chosen to define the following four categories of space activity: pure government, privatization, commercialization and pure commerce.

We have endeavored to develop a "Commercialization Matrix" (Figure 1) that represents the various ISS assets, development, operations, utilization, and augmentation while introducing the concept of commercial migration.

Pure Government

Pure Government space activity is defined as a government entity such as NASA, conducting its activities through the purchase of products and services from government contractors. The ISS program is currently 100% government financed for design, development and assembly. Even early utilization of the research and development assets of the ISS will be dominated by government supported researchers.

Privatization

"Privatization involves a private sector, profit-seeking entity carrying out functions previously the responsibility of government. The government is still the sole or primary customer for these activities and funds the private entity to carry them out. The objectives of privatization include using the presumed efficiencies of the private sector to reduce the cost of the activities that are privatized, thereby reducing the demands on the government budget; to remove the government from direct involvement from activities that are carried out on a repetitive basis; and to reduce the number of government employees involved in such activities."[2]

The efforts of NASA to privatize the shuttle operations through the Space Flight Operations Contract (SFOC) and their ground control network through the Consolidated Space Operations Contract (CSOC) are the best recent examples of privatization.

Commercialization

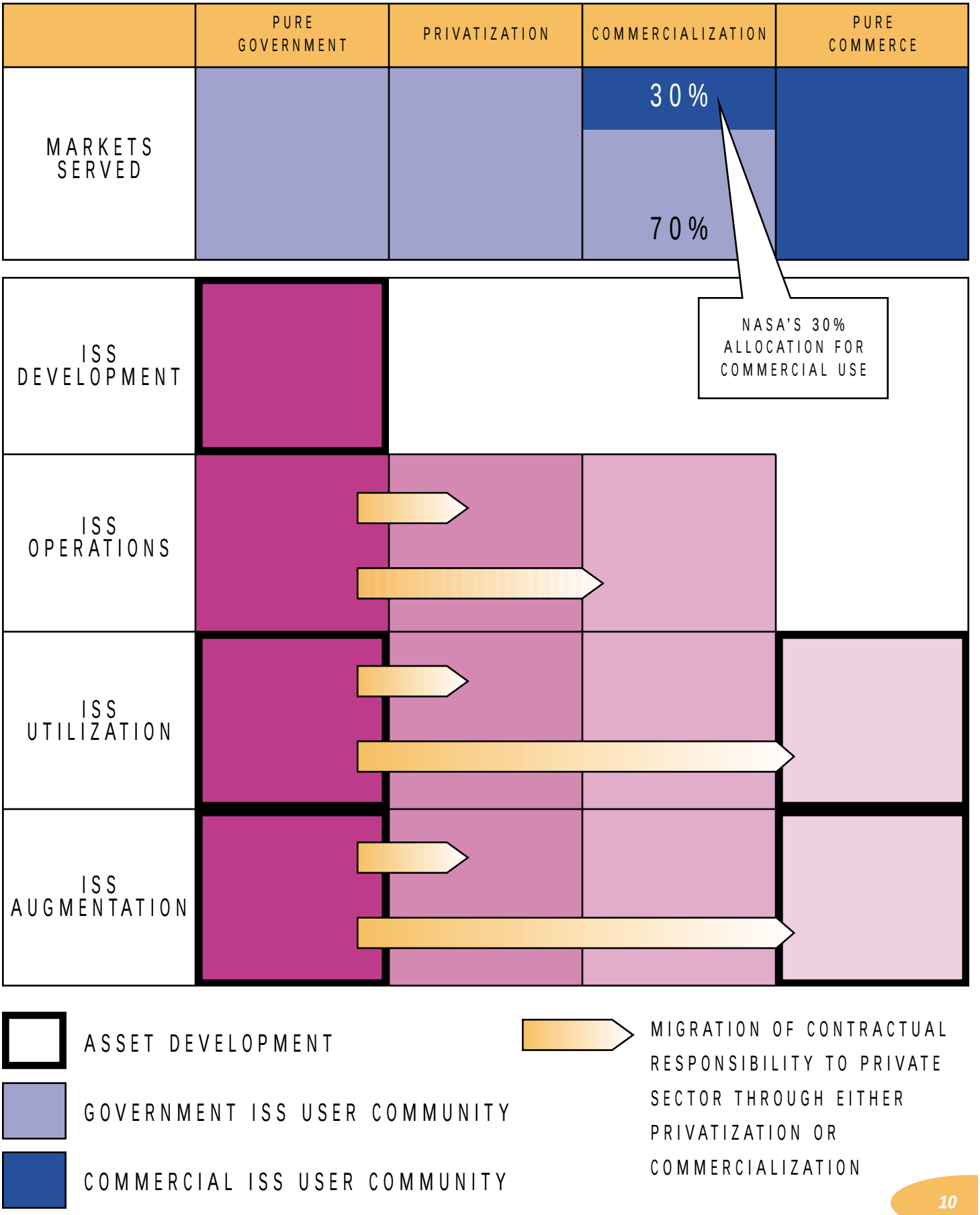
The second stage of commercial activity in space commercialization occurs when the government makes available to a private entity a public asset, or control of that asset to be used in serving the needs of both government and commercial customers.

Pure Commerce

The final stage of private industry moving into space activities we have defined as "Pure Commerce." This involves a private sector profit-seeking entity using private capital to carry out activities intended to result in products or services that can be sold at a profit through the marketplace to private sector customers, both in space and on Earth. Examples of such could be either privately built space hardware – potentially connected to the ISS – leased to both commercial and government users, or the licensing of the ISS logo and imagery for use in commercial products and services.

[2] Logsdon, John: "Commercializing the International Space Station: current US thinking."

FIGURE 1: COMMERCIALIZATION MATRIX



THE TREND TOWARDS COMMERCIAL SPACE

Commercial Space Emerges

The recently emerging commercial space market is beginning to drive much of the investment in next generation satellites, launch vehicles and spaceport infrastructure. The trend towards commercial space is also influencing NASA's approach to operation, utilization and augmentation of the ISS. Understanding the forces driving space commerce is critical to estimating the potential for commercial utilization of the ISS.

Until recently, government has been the primary driver of the space sector of the economy. The vast majority of dollars invested in the development of satellite systems for positioning, communications and imaging, have come from either civil or military procurement programs. Industry has traditionally been unwilling or unable to embark upon major development programs without the support traditionally provided by a government contract.

In recent years, the model for space development has begun to shift. Government is no longer a monopsony purchaser of services from the aerospace contractor community – rather, numerous commercial systems are now being deployed whose primary customers are businesses or consumers, and not government. This shift is most visible in the Geostationary Earth Orbit (GEO) communications market, which has been developing commercially for several decades. The projected increase in LEO satellites continues to drive much of the investment in the development of next generation launch vehicles.

In the telecommunications area of commercial space, private sector participation has recently surged. The best example of the commercial value of space was seen during the recent Federal Communications Commission (FCC) spectrum auction. Much of the spectrum allocated for space-based communications services was bid for aggressively. The revenue generated during these auctions is a clear indicator of the value the private sector places on commercial activity in space. Over the course of 22 auctions, a total of $23.6B had been committed by over 750 concerns with well over 1,400 having submitted bids (Table 1). While not all of this amount has been collected, due in part to withdrawals and canceled projects, the magnitude of capital in play for space-based telecommunications systems is undeniably significant.

TABLE 1: FCC SPECTRUM AUCTIONS

AUCTION	TYPE OF AUCTION	NET VALUE $	# OF BIDDERS	# WON
Auction 1	Nationwide Narrowband PCS Auction Charts	$650,306,674	27	6
Auction 2	Interactive Video and Data Services (IDVS) Auction Charts	$213,892,375	289	178
Auction 3	Regional Narrowband (PCS) Auction Charts	$394,835,784	28	9
Auction 4	A & B Block Auction Charts	$7,736,020,384	30	18
Auction 5	Block PCS Auction Charts	$9,270,319,265	255	87
Auction 6	Multipoint/Multichannel Distribution Services Auction Charts	$216,397,391	155	67
Auction 7	900 MHz Specialized Mobile Radio Service Auction Charts	$204,399,124	123	80
Auction 8	Direct Broadcast Satellite 110 Degrees (DBS) Auction Charts	$682,500,000	3	1
Auction 9	Direct Broadcast Satellite 148 Degrees (DBS) Auction Charts	$52,295,000	2	1
Auction 10	Broadband PCS C Block Re-auction – Charts	$697,213,950	32	7
Auction 11	Broadband PCS D,E, & F Block Auction Charts	$2,523,428,304	153	125
Auction 12	Cellular Unserved Auction – Charts	$1,842,533	22	10
Auction 14	Wireless Communications Service (WCS) Auction – Charts	$13,639,132	24	17
Auction 15	Digital Audio Radio Service (DARS) Auction – Charts	$173,234,888	4	2
Auction 16	800 MHz Specialized Mobile Radio Service (SMR) Auction – Charts	$96,316,196	62	14
Auction 17	Local Multipoint Distribution System (LMDS) – Charts	$578,749,385	139	104
Auction 18	220 MHz Service – Charts	$21,843,792	54	44
Auction 20	VHF Public Coast Stations Auction – Charts	$7,485,752	8	4
Auction 21	Location and Monitoring Service Auction – Charts	$3,453,308	5	4
Auction 22	C,D,E, & F Block Broadband Auction – Charts	$412,840,945	67	17
Total		$23.6 Billion	1,482	795

Source: FCC

Commercial Satellite Services

The shift toward commercial space is most apparent in the recent development of a wide variety of telecommunication ventures to serve consumers with voice, paging, internet and imagery services. These systems are financed primarily through a combination of private and public equity and debt. Table 2 provides a partial list of the major planned telecommunications systems and the projected investment required for their deployment.

TABLE 2: MAJOR TELECOMMUNICATIONS SYSTEMS

SYSTEM	NUMBER OF SATELLITES	PRIMARY MISSION	COST	OPERATIONAL DATE
Iridium	66	Voice, paging, data, fax	$3.5 billion	Late 1998
Teledesic	288	Broadband internet, high quality voice, computer networking	$9 billion	2003
Globalstar	56	Voice, data, fax	$2.6 billion	1999
ICO	12	Cellular services, fax, paging	$2.6 billion	2000
AceS	2	Voice, data, fax, paging	$900 million	1999
Agrani	2	Voice	$710 million	2000
Orbcomm	48	Data, messaging communications	NA	1995
Skybridge	48	Global broadband telecommunications	$4.2 billion	2001
Spaceway	3	Voice, data, video, audio, multimedia	$1.4 billion	2002

Source: KPMG research, FCC filings, Company publications

The first two operational commercial LEO systems, Orbcomm and Iridium, are currently in the process of building the subscriber base for their respective systems. The success or failure of these companies to reach their financial objectives will test the validity of the market forecasts of unmet worldwide demand for data and communications services that drove the investment in these systems.

Commercial Launch Services

The projected growth in satellite constellations has driven a dramatic increase of activity in the launch services sector. Boeing and Lockheed Martin and numerous privately financed start-up Reusable Launch Vehicle (RLV) companies – such as Pioneer Rocketplane, Kelly Space and Technology, Kistler and Rotary Rocket – all plan to serve the commercial market. In addition to commercial markets, these companies also plan to offer low-cost launch services to the US government. The use of economies of scale and other operational efficiencies will allow these companies to potentially reduce cost of access to space.

Commercial Spaceports

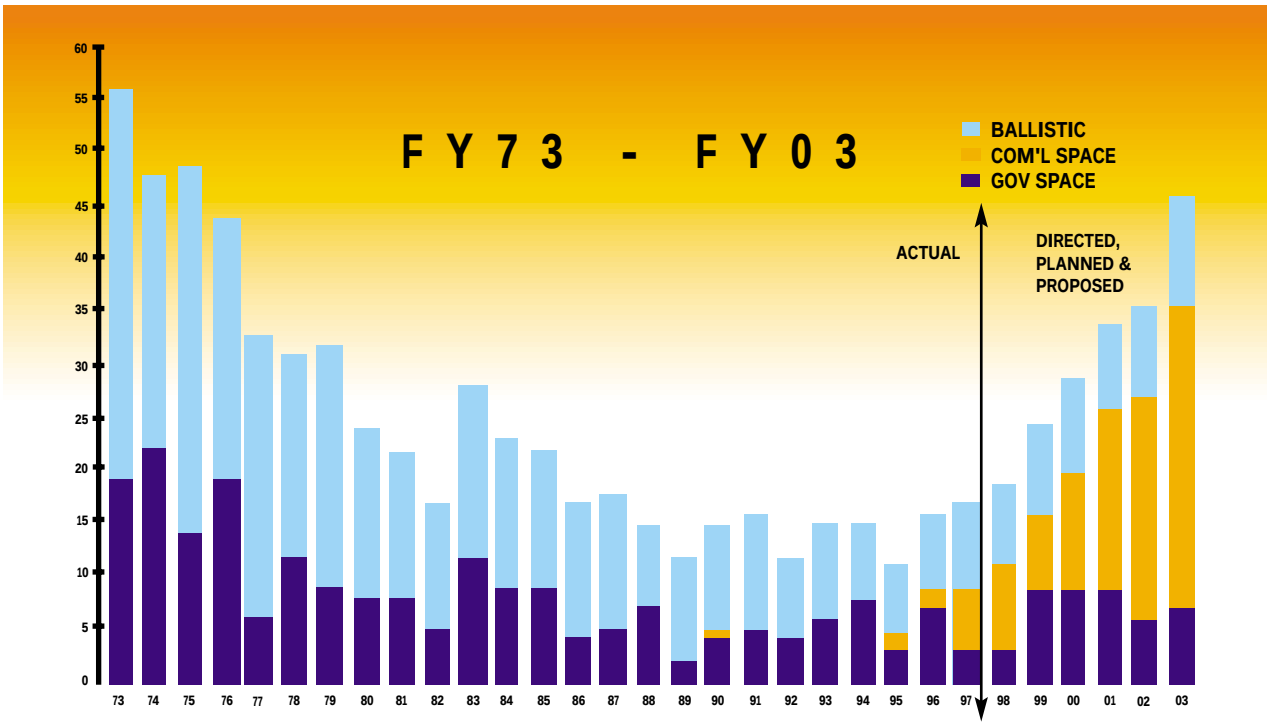
In the past few years, the spaceport market has also seen significant movement towards commercialization. Facilities such as Spaceport Florida, Kodiak Island in Alaska, Wallops Island in Virginia and Space Systems International in California are being developed and operated to service the growing number of satellite launches. In addition, many States and local governmental organizations have been preparing plans to enter into the commercial launch arena in hopes of attracting Lockheed Martin's VentureStar program as its base of operations.

The launch infrastructure segment of the industry value chain has long been dominated by US Air Force and other agencies conducting launch operations at Vandenberg Air Force Base (VAFB) and Cape Canaveral Air Station (CCAS). In the past few years however, a major change has begun to take place within the industry. 1998 marked the first year in which launches of commercial payloads exceeded the number of launches for government payloads from VAFB (Figure 2).

Government's Role in Space

The implications of this shift from majority government customer to majority commercial customer are profound. It indicates that the launch industry may finally begin to emerge as a truly self-reliant sector

FIGURE 2: COMMERCIAL VS. GOVERNMENT LAUNCHES, VAFB



Source: USAF Briefing "Space Infrastructure in California"

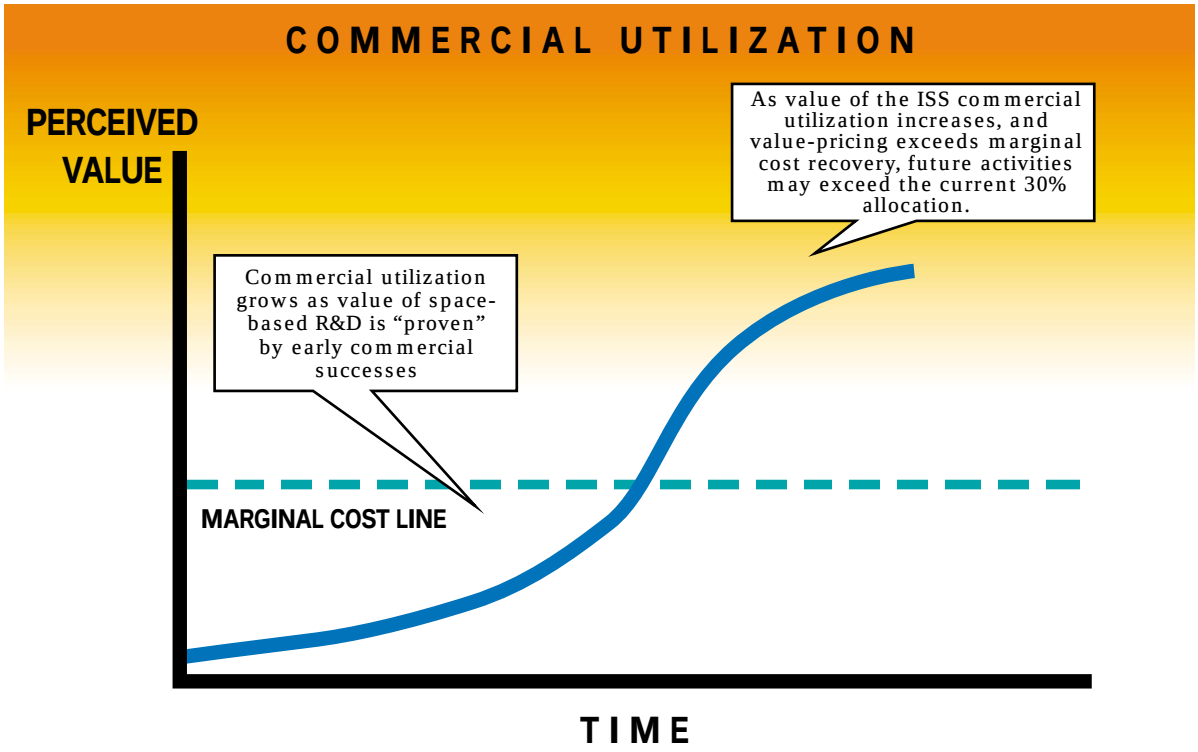
that is no longer dependent on direct or indirect subsidization by the US government. Although much of the projected "dominance" of commercial launches in the coming years is predicated on LEO telecommunications systems successfully finding financing, it is clear that the US government is no longer a monopsony purchaser of launch services.

Impact on Commercialization of the ISS

The overall trends toward commercial space that are driving the consideration of commercial utilization of the ISS are as follows:

- The value of commercial space as an operational platform is fairly well understood in the telecommunications market;
- Privatization of space operations through contracts such as SFOC and CSOC are providing a possible path for eventual commercialization of the ISS;
- The market potential for commercial utilization of the ISS may be realized (Figure 3) contingent upon the perceived value of ISS resources exceeding the cost of doing business.

FIGURE 3: ISS COMMERCIAL UTILIZATION TAKE-UP



SUMMARY OF FINDINGS

The following findings regarding commercial utilization of the ISS were developed during the course of this study. Our efforts took into consideration the trends related to commercial space, the market research reviewed and the input of the CSVAT.

Market Research Data Limited

Very little relevant market research for commercial use of the ISS was found during the course of this study. The commercial space market research conducted by the private sector is largely unrelated to the science and technology mission of the ISS. Outside of a few proprietary commercial research reports performed by aerospace companies for very narrow applications of existing space assets, we were unable to acquire or identify any significant body of commercially-funded market research on the value of the ISS for private sector use.

Low Levels of Private Sector Interest

To date, the level of private sector financial involvement in space-based research has been insignificant in comparison to the levels of government-sponsored research. Since the mid-1980's, NASA has attempted to foster industry collaboration with government and university research through the Centers for the Commercial Development of Space (CCDS); the former CCDS' are currently called the Commercial Space Centers (CSCs). According to CSC published data, there are a combined total of 264 CSC affiliates, 183 of which are commercial in nature. The commercial partners of the CSCs have invested $430 million in commercial space research. Even with these agreements between the government, industry and academic entities, the economic success of the CSCs in the commercial application of space research has been limited, due primarily to the impediments highlighted in this report.

The technology adoption curve describes the behavior of consumers (companies and/or individuals) when provided with a new enabling technology or innovation. A recently-published article summarizes the process and issues surrounding technology adoption; its relevance to assessing the ISS market

[3]"One of the most profitable strategies firms follow is that of bringing innovative products to market and gaining first-mover advantage over competitors. The need to provide innovative products is increasingly felt in light of global competition, more parity products, shorter product life cycles, and increasingly sophisticated and knowledgeable consumers. Yet, innovations are also risky; some succeed and many fail (Cooper 1993). One important determinant of an innovation's success is consumers' beliefs about the viability of the innovation; beliefs that are likely to evolve as the innovation changes and consumers move through the stages of the adoption process. While not necessarily limited to markets for high-tech products, these concepts are particularly appropriate in high-tech markets because of the effect of rapidly evolving technology on product markets and consumer purchase decisions.

Much research has studied both innovations and the consumers who adopt them. Adoption research, based primarily on the work of Rogers (1962), has focused on general reasons for adoption at an abstract level. Other researchers have examined the characteristics of adopters, trying to answer such questions as what distinguishes the "innovators" from the "laggards." Perhaps the most prolific stream of research has focused on timing, or how fast the innovation will diffuse, and factors such as price and advertising, which affect timing. The Bass (1969) model and the numerous extensions that have followed exemplify this work.

potential is clear.[3] Essentially, utilization of space as a research environment by commercial industry is still in the "early adopter" stage of its technology adoption curve. In order to move to the "mass market" stage of the curve, a significantly larger base of experience will need to be generated by industry and academia.

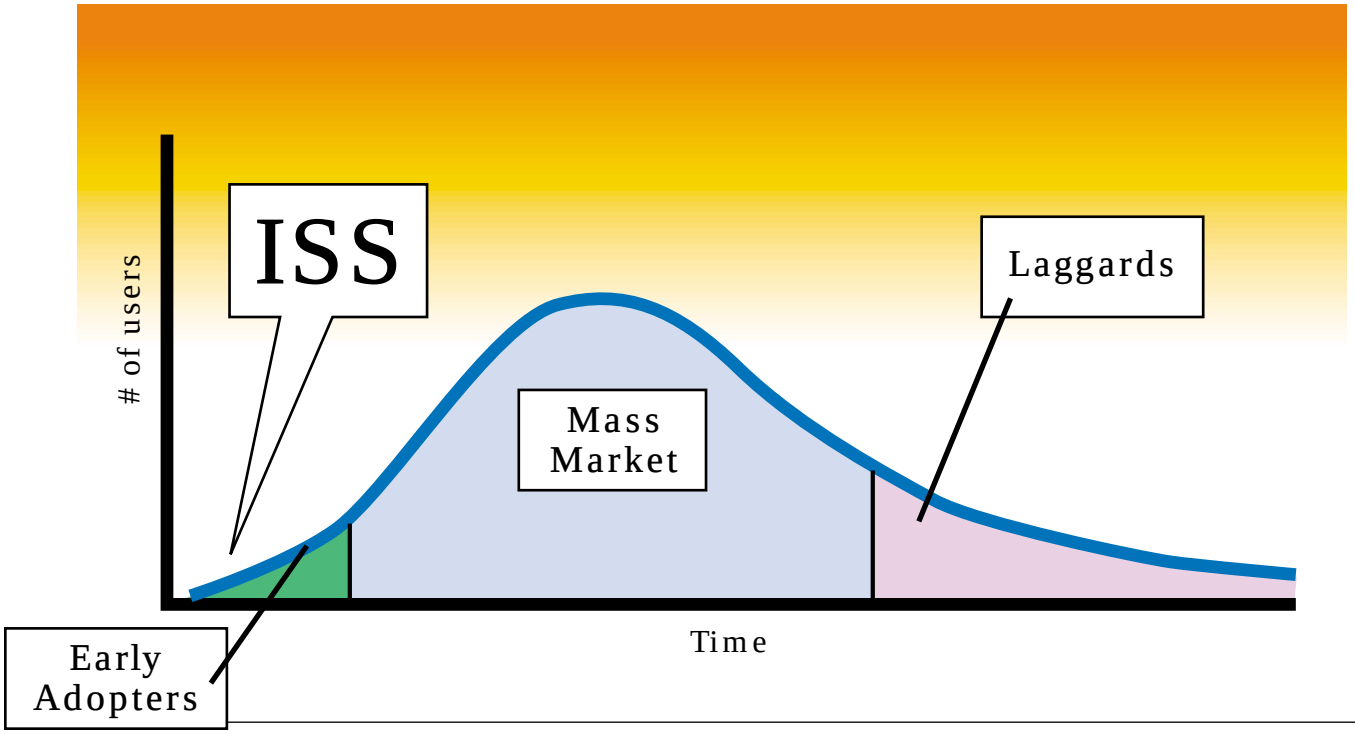
Figure 4 provides a graphical representation of the technology adoption curve and our assessment of the relative placement of the ISS within that framework.

Questionable Value of ISS Market Demand Forecasts

Conducting an objective market study to evaluate the potential commercial utilization of the ISS - given its current state of development (Figure 4) - is a difficult task. This is due to the embryonic nature of the markets which are being evaluated.

The ISS has been promoted as a platform for the development of new technologies, processes, or products to improve life on Earth and create new economic opportunities. The research environment provided by the ISS in LEO is characterized by a number of unique attributes, including extended duration microgravity, an ultra-vacuum environment, and a unique vantage point.

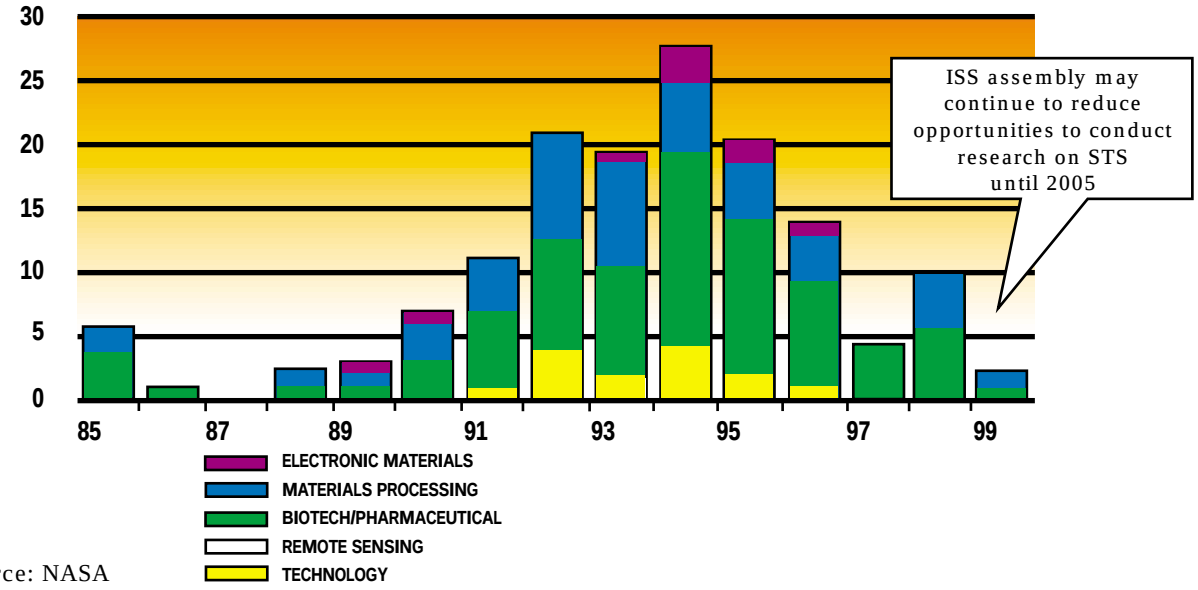
FIGURE 4: THE ISS AND THE TECHNOLOGY ADOPTION CURVE



Recently, there has been particular interest in "really new" products evidenced by special issues devoted to this topic by Journal of Marketing Research and Journal of Product Innovation Management in 1997. The practitioner community has seen an ever-increasing array of seminars and business press books on the topic. Of particular note are Geoffrey Moore's books, Crossing the Chasm (1991) and Inside the Tornado (1995). Moore blends Rogers' work with his experience to offer an "updated" version of the adoption cycle suited for

Since 1985, approximately 150 commercial flight experiments have flown on the Space Shuttle. Unfortunately the availability, and therefore use, of the Space Shuttle for commercial research has been declining for the past four years (Figure 5). This problem will continue unless ISS flights include significant commercial payload opportunities.

FIGURE 5: ANNUAL COMMERCIAL EXPERIMENTS FLOWN ON STS



Source: NASA

Given that the current level of private sector involvement in human space is still quite small, it may be necessary for government to maintain its dominant role in space-based R&D for the foreseeable future. If at some point the perceived value of space-based R&D by industry is great enough to warrant private-sector participation, rapid uptake of the available capacity of the ISS would likely follow.

high-tech markets. To succeed, Moore stresses that firms must understand and respond to the needs of different consumer groups at different stages of the adoption cycle. Importantly, "mainstream" market consumers have needs beyond the product itself including references from other adopters, established standards, lots of support, and a preference for large, well-established companies (Moore 1991:13). The attractiveness of an innovation is also affected by factors beyond the characteristics of the product itself, for example, the reputation of the firms offering the product, who is using the product already, and, for many technical products, whether a uniform "standard" has been set. Moore (1991) illustrates this well when he discusses market pragmatists-those buyers of high-tech products who buy during rapid market growth-as caring about "the company they are buying from, the infrastructure of supporting products and system interfaces, and the reliability of the service they are going to get" (p. 43).

It is important to note that attractiveness can evolve over a product's life. A shortcoming of much research studying innovations is that the innovation is assumed to remain unchanged over its life. It is more realistic to recognize that the innovation changes over time and that, as a result, consumer perceptions and evaluations can also change.

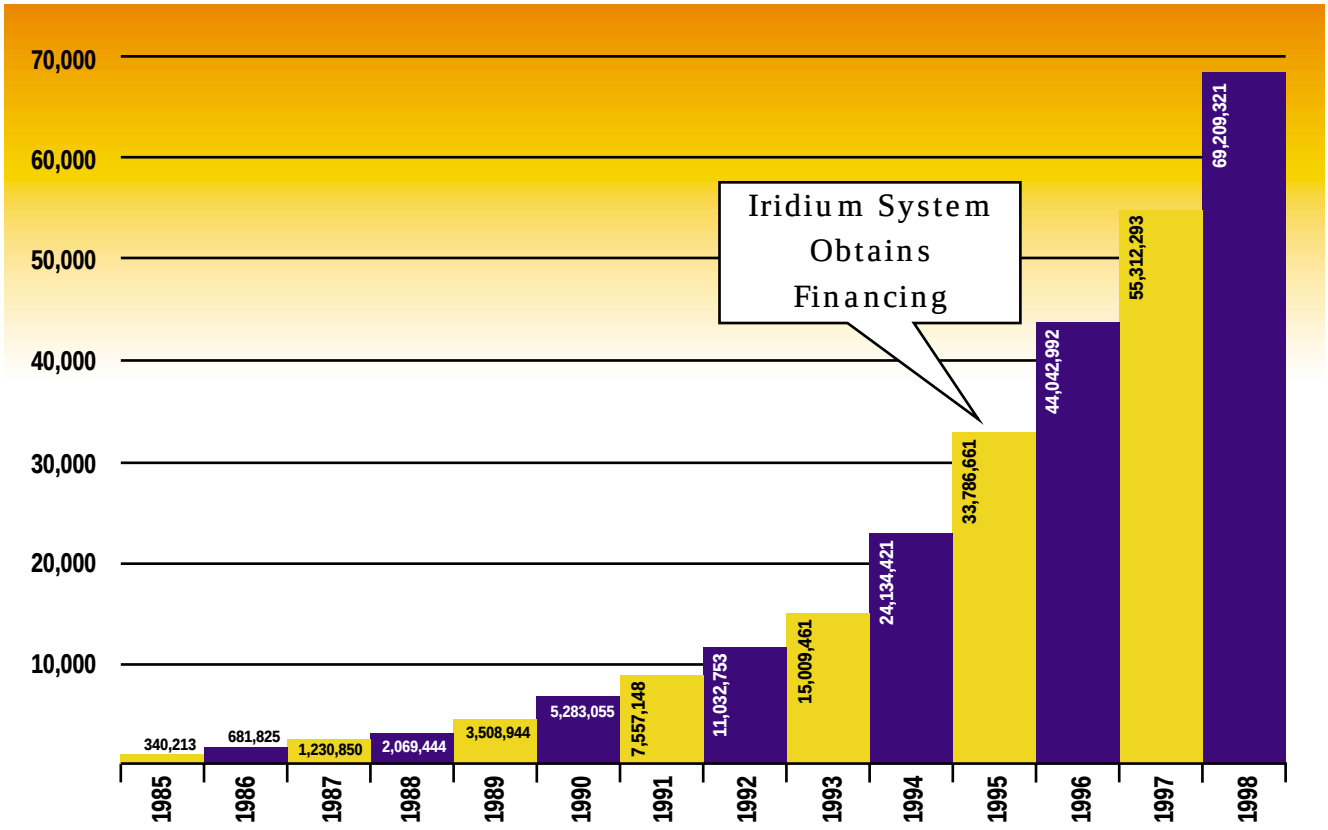
It is possible for a consumer to perceive a product category as attractive but have a low likelihood of adoption due to lack of immediate personal need. However, higher attractiveness should generally increase the likelihood of adoption because it implies the consumer recognizes the potential utility and viability of the product category. Conversely, it is unlikely a consumer would adopt a product with low attractiveness."

Boyd, Thomas C; Mason, Charlotte H : "The link between attractiveness of "extrabrand" attributes and the adoption of innovations" Journal of the Academy of Marketing Science, Summer 1999

Extended duration human-tended microgravity – as the primary capability offered by the ISS – is an essentially undeveloped technology in the earliest stages of research, with no analogous capability on Earth. As a result, it is questionable to attempt to forecast - with any accuracy - market demand for such a new capability. Similarly, it would have been highly unlikely for Iridium to obtain private sector financing in 1980 due to the lack of a developed terrestrial market for wireless telecommunications services. Early in the development of Iridium, cellular adoption rates were relatively low. As the cellular market matured and the operating economics of the terrestrial wireless business became clearly understood, the business case for a space-based alternative - Iridium - could be closed (Figure 6).

As recent events surrounding Iridium have shown, even when the financial sector backs space-based businesses which either replace or supplement a terrestrial capability, there is no guarantee of profitability.

FIGURE 6: CELLULAR ADOPTION RATES AND TIMING OF IRIDIUM FINANCING

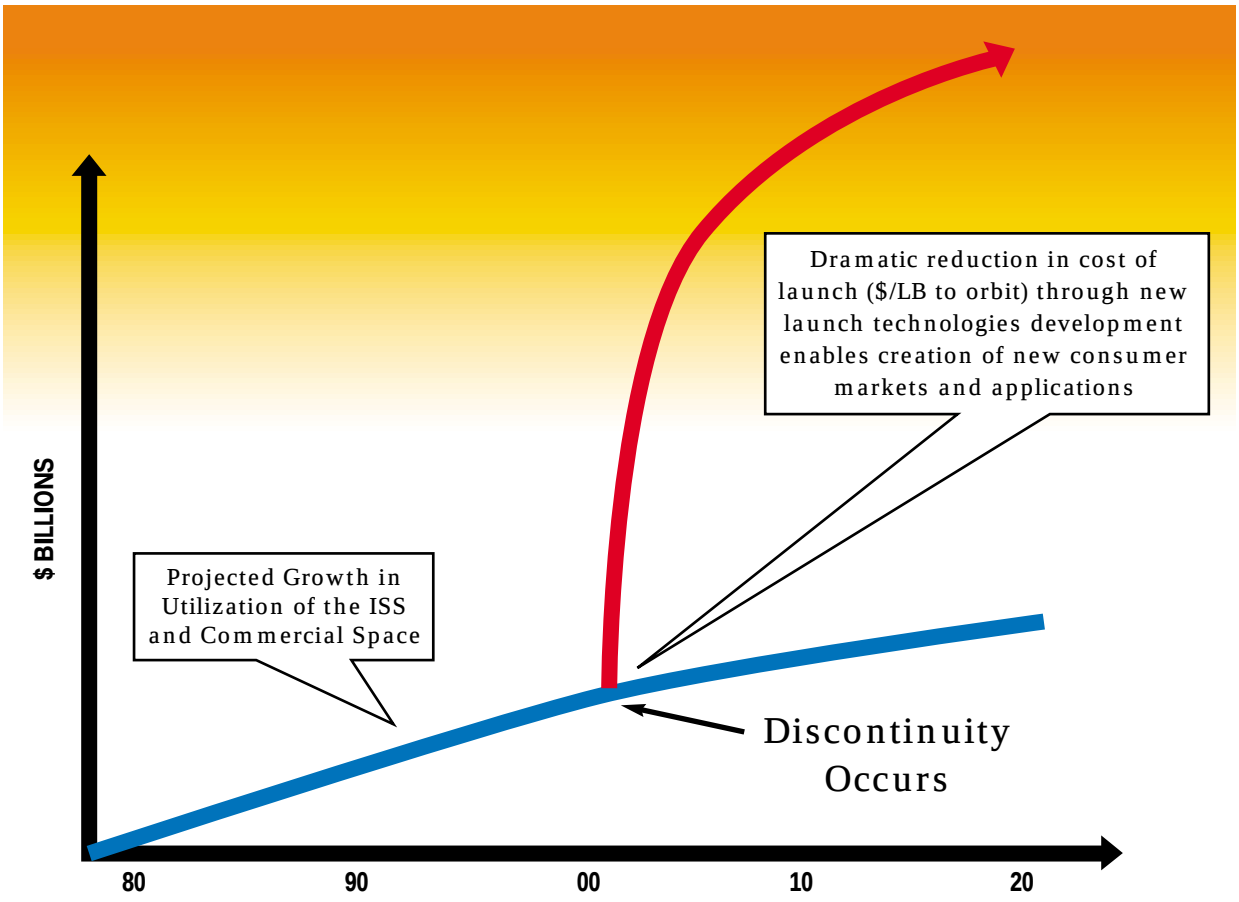


Impact of High Launch Costs

The cost of access to the ISS via shuttle is currently prohibitive to the private sector. Commercially backed R&D will not occur if required to pay $7,500 to $10,000/lb for transportation to the ISS. Until a substantial lowering of launch costs occur, this fundamental stumbling block to space commerce will remain.

A number of papers have been produced by space advocacy organizations proposing many new commercial activities in space. These studies project significant near term markets for space commerce (e.g. space tourism), capable of generating billions of dollars of revenue for private sector space companies. Unfortunately, as with space R&D markets, most humans-in-space oriented commercial markets require a radical lowering of cost per pound to orbit. (Figure 7). Until the costs of space access are lowered, the relevance of these markets to the commercial utilization of the ISS in the near term, is limited. Therefore, a primary NASA goal should be to aggressively nurture a variety of advanced RLV technologies in order to lower launch costs as rapidly as possible, thus enabling positive market discontinuities.

FIGURE 7: NOTIONAL EFFECT ON MARKET OF SIGNIFICANT LAUNCH-COST REDUCTION



Entertainment, Education and Advertising Promising

Based on our research, the earliest pre-assembly-complete opportunities for significant revenue generating commercial activity on the ISS may be found in the fields of entertainment, education and advertising (e.g. licensing, for-profit educational programming, corporate sponsorship, etc.). The public has long been interested in space exploration and human spaceflight, and the ISS represents an opportunity to further that excitement. The last two decades have witnessed a relative decline in attention paid to space activities due to the perception amongst the population that space activity has become routine. Judging from the high levels of public interest recently witnessed in the Mars Pathfinder and John Glenn missions, it appears that this trend can be reversed. A strong uptick in public interest in space activities could allow significant opportunities for expanding commercial utilization of the ISS.

While entertainment, education and advertisement do not fall within the core science and technology mission of the ISS, they potentially offer a near-term revenue stream that could be used to offset the cost of longer-term R&D projects for which the ISS was designed. In addition, entertainment, education and advertisement uses of the ISS in the near-term will increase awareness of the ISS in the eyes of the commercial user community and, as a result, would have a positive effect on the overall level of commercial utilization of the ISS.

Long Term Prospects

In the long term, we believe that the ISS could see significant commercial demand for its R&D capabilities, as the results from early experiments reach commercial maturity and are successful in generating measurable financial returns for the private sector. If this private sector interest should outstrip the capabilities of the ISS, it would create the demand necessary for the development of privately financed orbital facilities thus completing the migration to pure commerce in space.

IMPEDIMENTS AND MITIGATIONS TO ISS COMMERCIAL UTILIZATION

ISS COMMERCIALIZATION STUDY RESULTS

During the course of our meetings, the CSVAT members supplied our team with numerous first hand experiences of failures and frustrations in commercial space activity. From this history and KPMG's own analysis, we have distilled a list of key impediments that hinder the commercial use of the ISS. We have also developed a series of recommended mitigations to these impediments.

It is important to recognize that even with the full resolution of these impediments there is no guarantee that commercial utilization of the ISS will occur. It is clear however, that without mitigation or full resolution of these impediments, minimal effective commercial activity will take place on the ISS.

The impediments discussed herein represent only the most significant impediments identified through the development of this report; additional impediments may yet appear, and will have to be proactively dealt with as they are uncovered.

AWARENESS

Awareness Impediments

- Lack of awareness regarding the history of microgravity research on Shuttle and other facilities is an impediment to commercial activity on the ISS. If the benefits of space-based research are not understood, then meaningful value cannot be attached to it.

- Currently the wide variety of ISS facilities, functions and capabilities are not well understood by the prospective non-aerospace user communities. These would include not only use of the pressurized laboratories but the external payload sites and other non-traditional uses as well.

Awareness Mitigations

- Continue to support the CSCs, currently the most effective NASA organizations for promoting the commercial value of space-based research to industry. By building long-term relationships between industry and academia, the CSCs encourage industry investment in space research. As a result, the CSCs are in a position to provide highly targeted outreach in the short-term, which increases awareness of commercial ISS opportunities within some of the most promising industry sectors.

- Developing and executing a comprehensive and targeted marketing strategy to increase potential ISS utilization by the commercial sector will help resolve impediments due to lack of awareness. An essential component of the strategy should be focused on effectively communicating information regarding the history of microgravity research, its success stories, the valuable capabilities of the ISS and the attributes associated with those capabilities. The communications efforts should target the decision-makers of all the potential user communities including traditional aerospace and non-aerospace industries by:
  - Publishing articles in the appropriate trade and industry journals;
  - Giving presentations regarding Shuttle successes and ISS capabilities at relevant, trade and industry conferences;
  - Conducting town hall meetings with ISS and industry representatives to promote ISS opportunities and its potential value;
  - Aggressively promoting success stories relevant to ISS capabilities.

POLICY AND REGULATORY

Policy and Regulatory Impediments

- The necessary information regarding ISS-related policies and regulations on such things as pricing, exclusivity, proprietary information, resource allocation, scheduling and other relevant issues need to be resolved. A firm understanding of the policies and regulations derived from the resolution of these issues are critical to the private sector decision-makers. Without this information, the potential commercial users are unable to compare the costs, risks and feasibility of conducting space-based R&D with terrestrial alternatives. Most importantly, it makes it difficult to determine the value of utilizing the ISS for their organization.

- The current design versus performance-based specifications - created to ensure an environment of operational safety that define the Space Shuttle and the ISS - conflict with time-critical commercial users. Unless this conflict can be resolved, while still preserving necessary safety features, NASA's operational constraints will continue to limit commercial utilization of the STS and the ISS.

Policy and Regulatory Mitigations

- It is essential that policies and regulations be developed and communicated to the potential user community as early as possible. The sooner those issues are resolved, the greater the likelihood of early commercial participation. By taking into consideration the needs of the potential user community during the development of the commercial operations policies and regulations, the ISS may find itself a more competitive, attractive and user-friendly service.

- Reduce the constraints on operation and utilization of the Shuttle and ISS by allowing for reasonable program risks. Regulatory procedures and processes should be evaluated with an eye to reducing the total burden and duration of the entire process, while still maintaining sufficient safety standards.

FINANCIAL

Financial Impediments

- The price of access to the ISS for the traditional customer by utilizing the Shuttle is just too high. It would be difficult to justify the expense of going to the ISS for almost any purpose if the customer must face the $7,500 - $10,000/lb. cost of Shuttle transportation.

- The perception of the current regulatory process for using the Shuttle and the ISS is considered to be time intensive and hence expensive. In the commercial world, time-value of money relationship is paramount. Even if there were no delays in Shuttle launch schedules and the paperwork and review processes went smoothly, the overall system would still be too lengthy and complicated in its current state. Industry R&D timetables are structured around the commercially driven, extremely rapid lifecycles they face, not currently compatible with Shuttle turnaround times. In contrast, the NASA process for manifesting a payload on the Space Shuttle can take as much as 24 months, thereby making the experiment results largely irrelevant in the fast-paced world of commercial product development.

- A fundamental lack of available capital to finance private commercial activities in the areas of microgravity research and other space-related activities, given the available terrestrial alternatives for investment, is a factor that will limit the potential commercial success of the ISS until the cost/benefit calculations are better understood.

Financial Mitigations

- Continue to explore and implement new mechanisms for reducing the costs associated with using the Shuttle and the ISS. The Shuttle is perceived to be one of the largest components of the potential total expense of the ISS. Reducing costs will not be an easy task but given the significance of the issue, it will be necessary.

- A significant reduction in the time required to manifest, integrate, launch and return a commercial payload is necessary to improve the utility of the ISS for commercial customers. Reducing the lead and turnaround times will make the ISS a more attractive option and will be fundamental to fostering private sector demand for the ISS. This would also include ensuring the

consistent availability of the Space Shuttle and the ISS for commercial customers until such time as alternative methods to access the ISS (e.g. RLV's) come into service.

- NASA and legislators may want to consider various potential tax credits that may assist in the creation of stronger commercial markets for the ISS. The CSVAT and KPMG believe that tax incentives could provide encouragement for investment in commercial activities aboard the ISS.

TECHNICAL

Technical Impediments

- The ISS was designed primarily to meet the needs of government research. As a result, some in the private sector R&D community question the value of the ISS for conducting commercial activities. Some of the capabilities that will become available on the ISS are already crudely, but relatively inexpensively, simulated on Earth (e.g., vacuum chambers, drop towers, bioreactors, etc.). The truly unique attribute of the ISS - extended duration, human-tended microgravity – is not at this time fully understood and thus not in wide demand by the private sector.

- For microgravity research on materials or drugs, the results must be usable in a production environment on Earth, otherwise there is no value in conducting the research until long-term commercial facilities are available in space.

- The private sector has not shown interest in conducting pure scientific research not tied to a measurable return on investment. While there are some research areas in which applied R&D could be conducted on the ISS, the ISS is primarily designed for conducting basic R&D. This is in direct conflict with the industry trend away from basic, towards more rapid turnaround applied R&D.[4]

- The limited resources on the ISS in terms of available power, rack space, crew resources, data and other communications packages etc., are perceived as a barrier to commercial growth in its current configuration.

Technical Mitigations

- Emphasize the specific attributes of the ISS that are not reproducible through any other technology means and target efforts to show how beneficial the ISS could be to the individual segments of the potential user community. By providing the specific information that addresses the needs of that customer segment, the value of the capability will be more easily understood by the user.

[4]National Science Foundation, Division of Science Resources Studies - "National Patterns of R&D Resources: 1998", NSF99-335, by Steven Payson

- In order to encourage companies to consider investing in use of the ISS for conducting basic R&D, create a mechanism for translating the R&D output into commercially marketable products. As an example, in the area of pharmaceuticals, R&D gathers research data on the ISS for dissemination to the private sector, which can then be used for products and services developed on the ground. Unless the terrestrial value and transferability of space-based R&D can be demonstrated to companies, the level of their interest will not improve from today's extremely low levels.

- NASA should strive to improve upon existing mechanisms such as the CSCs, promoting broader industry/academic consortium participation to spread the risk and cost of conducting basic R&D. This would also provide the important benefit of rapidly disseminating news of successful research and any "home-run" successes to the larger commercial user population.

- Look for opportunities to augment ISS capabilities so they are more closely in line with private sector needs (e.g. enhanced communication systems, power supply or other dedicated commercial facilities, etc.).

CONCLUSIONS

Based on the results of our review of the available information, and input from the CSVAT, the near-term market potential for commercial utilization of the ISS for long-duration human-tended microgravity R&D is limited. Low levels of commercial sector interest, long lead times, unpredictable scheduling of payloads, and high integration and launch costs continue to inhibit significant market demand at this early stage of the ISS program.

Opportunities for commercial activity in the areas of entertainment, education and advertising may be significant in the near-term. While these areas are not traditionally considered part of the core science and technology mission of the ISS, they do offer a potential near-term revenue stream that can be used to offset other ISS costs. This will increase awareness of the ISS among the intended user communities and would likely act as a catalyst to stimulate other commercial utilization of ISS over time.

Even if the impediments identified in this study are overcome through a joint effort by NASA and industry, there is no guarantee that the ISS will see full paid commercial use of the 30% resource allocation as offered by NASA. It is clear however, that failing to resolve these impediments will most likely inhibit any significant commercial activity from developing on the ISS in the foreseeable future. As these impediments are resolved, commercial demand may justify the predictions of those who support commercialization as a primary goal of the ISS. Just as it would have been extremely difficult to predict the growth of the Internet and World Wide Web prior to 1994, it is improbable to accurately assess the level of impact an enabling technology such as the ISS could provide to the private sector.

In order for NASA to eventually meet its commercialization goals on the ISS, an independent asset manager should be considered to manage the commercial interests of the ISS including ground operations, transportation, and orbital transfer of commercial cargo. This entity must necessarily enable both the capture of non-traditional sources of revenue (e.g. entertainment, education and advertising) and maximize the commercial utilization of the ISS R&D capabilities.

The independent entity will be required to promote and develop awareness of the ISS and space-related opportunities to a larger user community across a range of industries. Only by establishing and actively promoting the ISS competitive advantages will the true value to Industry of its resources and capabilities be realized. Due to the need for international agreement and collaboration on the use of the ISS for advertising, sponsorship, licensing, and even R&D, the independent entity responsible for managing the ISS must also be able to deal effectively with the other partners in resource allocation and other issues as they arise.

In the long term, significant demand may be generated by the private sector for ISS capabilities. Only as a result of the early commercial success of ISS-developed products and services will significant demand for use of the resources available on the ISS appear. If this demand should outgrow the capabilities of the ISS, it may eventually lead to the development of additional privately funded orbital facilities such as free-flyers and multi-use business parks. Congress and NASA would be well served to remove the barriers to commercial use of the ISS, and to allow the marketplace time to develop and mature. Doing so would enable the realization of the true potential of the ISS to enhance life on Earth and positively impact the global economy.

APPENDIX A: LITERATURE REVIEW OF ISS-RELATED DOCUMENTS

LITERATURE REVIEW OF ISS-RELATED DOCUMENTS CONTENTS:

The contents of this appendix are focused on the ISS technical, political or programmatic issues, with a number of documents on issues of commercial space that may be tangentially related to the ISS. The documents listed in this appendix are neither intended to provide market forecasts nor to support a particular political position on the ISS. Rather, they are intended to give the reader a sense of the discussions that have taken place over the period of 1995 to present.

Brief summaries and/or abstracts of the following publications are provided as representative samples of the documentation reviewed and do not represent the entire body of work reviewed during the course of this study.

In addition, several of the documents do not adhere strictly to our study guidelines but were noted, due to their unique contribution, to the overall report. The papers are presented in approximate reverse chronological order, from 1999 to 1995.

ISS POSITION DOCUMENTS

The following reports and publications represent some of the more substantial ISS-related documents reviewed during this study. They were used primarily to provide a background for the research regarding the issues and opinions surrounding the ISS and its commercialization potential. This list provides a good representative sampling from which our findings and conclusions were derived.

AIAA 96-4471 Advanced Space Processing Concepts: From the International Space Station to the Lunar Territory, John L. Anderson, Advanced Concepts Office NASA, December 11, 1999.

> *"The commercial use of space has been the evolving theme of the space age since the Space Act of 1958. Since the establishment of Commercial Space Centers in 1985, space processing for research, development and eventual production of commercial products and processes has received increasing emphasis. Successes to date have been impressive and continued plans for Space Shuttle (STS) and the early stages of the International Space Station (ISS) should complete a broad base of data for commercial demonstration validation and application. Beyond that, two categories of space processing will emerge: 1) products resulting from using the unique conditions of space - largely projections of the currently perceived markets and capabilities and 2) operational capabilities to meet the unique requirements of large-scale space development."*

Commercializing the International Space Station: Current US Thinking, John M. Logsdon Space Policy Institute, George Washington 1998 pp 239-246.

> *"This article provides an overview of NASA's plans to encourage commercial use of the International Space Station (ISS). It examines the reasons driving such commercialization and highlights those private companies currently most interested in undertaking profit-making operations on the station, as well as discussing those activities most likely to be seen as commercial possibilities. The steps NASA is taking to stimulate private interest are enumerated. Various unresolved issues are raised, such as the legal issues associated with commercial research, charging policy for in-orbit operations and "metering" of in-orbit resources. It is noted that the international dimension of the ISS has thus far received little consideration in the USA."*

NASA Commercial Development Plan for the International Space Station, Final Draft, November 16, 1998.

> *"Objective: Long-Term:* To establish the foundation for a marketplace and stimulate a national economy for space products and services in low-Earth orbit, where both demand and supply are dominated by the private sector.
>
> *Short-Term: To begin the transition to private investment and offset a share of the public cost for operating the space shuttle fleet and space station through commercial enterprise in open markets.*
>
> *"Strategy: In partnership with the private sector, initiate a set of pathfinder business opportunities which can achieve profitable operations over the long run without public subsidies. Employ these businesses to break down market barriers in the near term and open the path for economic expansion. Initialize the process through the internal NASA study of pathfinder candidates, as a point-of-departure, with emphasis on pushing the envelope in terms of both public and private sector policies, procedures and cultural predisposition."*

NASA Internal Study: Potential Pathfinder Areas for Commercial Development of the International Space Station, Discussion Draft, October, 1998.

> *"An internal study was undertaken to identify pathfinder business enterprises with the potential to illuminate the commercial development of the International Space Station (ISS) and break down any perceived barriers to such development. The process used to identify the opportunities for commercialization, as well as potential pathfinders to evaluate these opportunities, is described in this report. The study concentrated on delineating the scope of potential commercial opportunities associated with the ISS, as well as evaluating, from the NASA perspective, several pathfinder areas of potential interest to the private sector. The NASA approach, evaluation criteria and results are provided in the following study report. As the plan for commercial development proceeds, it is anticipated that new business concepts will emerge and move to the forefront as private industry becomes involved. These concepts may be related to the pathfinders identified in this study, or they may represent entirely new and innovative space products or services. In either case, NASA intends to proceed with the most effective set, as determined by the new Government-industry partnership."*

NASA Reference Model: A Non-Governmental Organization for Space Station Utilization Management, Discussion Draft, October, 1998.

> *"The purpose of this reference model is to initiate a discussion of a new management approach to R&D in low-earth orbit consistent with the present and future constrained budget challenges.*
>
> *The objective is to create a non-government organization (NGO) for accomplishing an aggressive science, technology and commercial development program while simultaneously limiting government functions to policy and oversight. The ultimate success of the orbital R&D program depends equally on the efficient operation of the space and ground assets (laboratories, spacecraft, space station) and on the optimal utilization of the assets by the R&D and business communities. The utilization component must be managed in a manner which ensures productivity of the space station and other future ground and space assets. A NGO would serve as the interface between users and operators, in order to maximize the range of productive uses, as well as minimize the cost and schedule associated with conducting user operations in low-Earth orbit.*
>
> *The framework for a NGO should be based on a management structure that is representative of, and responsive to, a broad base within the utilization community. This management structure must possess a high degree of stability that will permit it to undertake and complete an integrated program over the expected life of the space station and associated assets."*

NASA Strategic Plan: Discussion Draft, October, 1998.

> *"We seek to bring the frontier of space fully within the sphere of human activity to build a better future for all humankind. Imagine new products based on space research, such as high-quality protein crystals to allow the design of new drugs for treating disease. Envision school children learning their lessons by telepresence instruction from the Moon. Imagine commerce flourishing in space, with solar power satellites, or a Martian powerplant to permit a permanent colony. These images are part of the Human Exploration and Development of Space (HEDS) Enterprise. The mission of the Enterprise is to open the space frontier by exploring, using and enabling the development of space and to expand the human experience into the far reaches of space."*

Microgravity and Space Processing, Robert Gustafson, AIAA, December, 1998.

"This year marked an important transition from conducting microgravity experiments on the Space Shuttle to preparing for experiments on the International Space Station (ISS). Despite some delay in the ISS assembly schedule, the NASA Microgravity Research Division continued to identify the scientific experiments that will be conducted on board the station once utilization flights begin. During the first three such flights, hardware facilities will be available in the areas of biotechnology, combustion science and fluid physics. The process of assigning experiments to the flights is nearing its final stages. In the interim, the ground-based research program continued to increase the number of investigators."

New Space Industries for the Next Millennium, Compiled by D.V. Smitherman Jr. Marshall Space Flight Center, Marshall Space Flight Center, December 3, 1998.

"New Space Industries for the Next Millennium is a final report of the finding from the New Space Industries Workshop held in Washington D.C. in February 1998. The primary purpose of this workshop was to identify what must be done to develop new markets, and to generate plans, milestones and new organization relationships designed to facilitate the goal of space development."

Commercial Space Business Parks: Final Report of Task Order #TOF-021 to Contract #NAS8-50000, Boeing Defense and Space Group, April 7, 1997.

"The study started with the results of the Commercial Space Transportation Study (CSTS), which was performed by six aerospace companies in 1993 and 1994. The CSTS identified a number of promising markets for commercial space transportation, provided that the transportation costs can be reduced to an acceptably low level.

Case studies were developed for commercial microgravity production, satellite servicing, entertainment and tourism. These case studies identified potential market size and helped to determine cost thresholds required for market development. They were further used to identify the required infrastructure and some of the critical policy-related issues that must be addressed before commercial space business parks can evolve. A rough schedule has been assembled to enable the market infrastructure, and policy resolution to move forward at a rate comparable to the low-cost space transportation development rate."

Large-Scale Commercial-Industrial Business in the Human Space Flight Area: Using the Space Station and its Support Program to Do So, T.F. Rogers, April 15, 1997.

> *"Commercial-Industrial business in the space information area -- communications, navigation, position-fixing and remote sensing -- is large and surging: nearly $10 billion per year including satellite launching and growing at a 10-12% rate.*
>
> *But, having spent $100s of billions in the human space flight area over four decades, there is still essentially no private commercial business going on therein.*
>
> *If we are serious about seeing the human space flight area opened up to private sector business creation and growth, then we must now begin the "gear-change" of moving from "cooperation" to "competition" in a free enterprise context, and from a complete dependence upon the long-term R&D process to seeing our entrepreneurial forces becoming directly engaged as well. The government roles are: to open up the ISS "frontier" with its presence there; to offer related markets to meet its own needs there in a way that will spur imaginative and aggressive risk-reward entrepreneurs to meet these market needs; and to develop/demonstrate further-out, lower cost, basic infrastructure that offers even greater promise if the financial-operational costs and risks can be reduced sufficiently..."*

The International Space Station Commercialization (ISSC) Study, Potomac Institute for Policy Studies, March 20, 1997.

> *"The present Administration, Congress, NASA, and the general public have all voiced support of commercialization of human space flight. The issues are who should do it, how it should be done, and how quickly.*
>
> *The purpose of the study was to address the three questions stated below. Its findings rested upon the assumption that the International Space Station (ISS) will be deployed by NASA within the next six years.*
>
> - *Are there compelling potential benefits from commercialization of human orbital space flight?*
> - *Are there viable areas of opportunity and plausible commercial ventures?*
> - *What, if any, should the government's role in fostering commercialization?"*

AIAA 97-0106 Planning for Microgravity Science Research on the International Space Station, J. Robey NASA Headquarters, January 1997.

"The microgravity research program for the International Space Station (ISS) is a key element of the strategic planning of the Microgravity Science and Applications Division (MSAD) at the National Aeronautics and Space Administration (NASA) headquarters. With limited logistics and operation resources anticipated for the early ISS, multi-user science instrument facilities are planned to support the needed capabilities for microgravity research.

This multi-user concept reduces the amount of hardware that must be launched to and returned from the orbiting Space Station. These microgravity research facilities focus on MSAD's five major science disciplines; biotechnology, combustion science, fluid physics, fundamental physics and materials science."

On Research Facilities Planning for the International Space Station, Space Studies Board, National Research Council, July 8 1997.

On July 8, 1997, Dr. Claude R. Canizares, chair of the Space Studies Board, Dr. Mary Jane Osborn, chair of the Committee on Space Biology and Medicine, and Dr. Martin E. Glicksman, chair of the Committee on Microgravity Research, sent the following letter to NASA Administrator Daniel S. Goldin.

"Among the challenges currently facing the space station program, those imposed by its flat development funding profile are clearly among the most demanding. It is the Board's understanding that, of the $2.1 billion yearly program budget, a substantial share of resources that had originally been intended for development of research facilities and outfitting is being allocated to development of the vehicle itself. As a result, key microgravity research facilities such as the furnace and the combustion and fluid science facilities that were to have been launched and put into operation in 2000 will now be delayed until 2002. Availability of gravitational biology habitat facilities will slip from 1999 to 2001, and the life sciences centrifuge will be delayed until at least the end of 2002. As a result, most of this research equipment will not be available to investigators until approximately five years from today."

Microgravity Research Opportunities for the 1990s, Space Studies Board, National Research Council, July 8 1997.

> *"Microgravity research is concerned with the effects of reduced gravitational forces on physical, chemical and biological phenomena. The scientific disciplines affected by gravity include fundamental physics, fluid mechanics and transport phenomena, materials science, biological sciences and biotechnology and combustion. It is especially noteworthy that these disciplines are laboratory sciences that inherently use controlled, model experiments. Many experiments require constant attention and frequent intervention by the experimenter, which distinguishes microgravity research from the observational space sciences. Microgravity research also spans both fundamental and applied sciences."*

Space Commercialization: An AIAA Information Paper, Prepared by the Public Policy Committee, American Institute of Aeronautics and Astronautics, January 1996.

> *"This paper summarizes the background and current status of commercial space activities, identifies the major problems (or barriers) faced by the U.S. in expanding and broadening these activities in the current changing global environment, and suggest actions to help resolve the problems and improve the environment for successful U.S. commercialization of space technologies."*

Historical Analogies Potentially Applicable to the Commercialization of Space Activities, G Harry Stine, 1996.

> *"Historical precursors and analogs are often invoked in an attempt to forecast or justify commercial space endeavors. This is especially true when space advocates attempt to make the case of getting government out of space and letting private space enterprise take over.*
>
> *However, history reveals that government participation in a technologically-based activity has benefits as well as disadvantages. Therefore, it may be well to proceed with caution when invoking historical examples as justifications. This calls for occasional sanity checks, particularly with regard to the current attempt to commercialize space activities. Keep in mind that the record shows that once a system is put into practice it rarely changed and then only with great difficulty, travail and often negative consequences."*

Private Sector Involvement in the Space Station Program, IEEE United States Activities Board, June, 1996.

"Consistent with the 'Space Privatization Activities' goals endorsed by IEEE-USA, the Space Station program is expected to serve as a hub for private activities. The private sector should be encouraged to provide the goods and services needed by ISSA over a transitional interval as our space industry moves from being government-supported to being driven by a free enterprise economy. Consequently, IEEE-USA recommends the following:

- *Promotion: The White House, Congress, NASA and members of U.S. industry should promote private sector involvement in ISSA through widely-publicized joint meetings and conferences which highlight the unique attributes of the space station environment. Private sector involvement will benefit our country through the ingenuity of U.S. industry leading to expanded commerce for space-based business founded on advance applied research.*

- *Involvement: The resulting private sector involvement will both enhance the U.S. benefits from the space station program and encourage private industry contributions to related research and development*

- *Business Development: The White House, Congress and NASA should help the private sector obtain and use engineering information about ISSA in order to open up new business opportunities in low-earth orbit and, ultimately, on the moon and beyond.*

- *Cooperation: Cooperation among industry, government and academia should be encouraged and fostered by the U.S. Government to help ISSA create larger economic markets for private-sector space developments and hasten space-related economic growth."*

AIAA 96-4297 An Integration Strategy for Worldwide Research Operations on the International Space Station, M. Uhran NASA, J. Sullivan SAIC, September 1996.

"The International Space Station, in its fully assembled configuration, will include over fifty payload sites capable of accommodating up to three hundred individual payload elements from around the world. Planning and scheduling research operations of this magnitude is unprecedented in the history of space flight. The physical and functional characteristics of the projected payload population have been analyzed from a statistical perspective, and operational models have been developed which employ recursive linear programming (r-LP) techniques.

Because research operations are relatively non-repetitive, and have uncertain predictability over time, standard operations research techniques, such as r-LP, are of limited utility. Instead, the search for the most effective planning and scheduling technique has lead to a unique multistage method, employing heuristic search techniques to achieve an approximate solution."

Bid Me Up, Scotty, John O. Ledyard, Caltech Social Science Faculty Profiles, 1999.

Description of Adaptive User Selection Mechanism (AUSM) using demand-based pricing as a means of allocating ISS payload resources (e.g. weight, volume, electrical power, manpower etc.)

"Ledyard, who in 1983 joined a group studying pricing policies at the Jet Propulsion Laboratory (JPL), thinks there is a better way. 'Any economist knows that pricing policy and the allocation of resources are intimately linked.' Those benefiting the most from a scarce resource will pay the most to secure its use, so auction it off. Assuming the bidders have some idea of their potential benefits, the bids become proxies for the payloads' real worth. The winning bids reflect the 'opportunity cost' of the payloads that don't fly --- the benefits lost to the unsuccessful bidders. Such as system is called 'demand-based' pricing."

International Space Station Teleconference: Make it Your Business, WHR/ NASA, 1999, 1998, 1997 etc.

Teleconference video tapes reviewed provided coverage of a number of issues surrounding space station commercialization including:

Space Station Partnerships
Discoveries in Fundamental Physics
Discoveries in Fundamental Science
Research Profile: Bristol-Myers Squibb
Commercial Space Policy
Investments in Space
Commercial Impact of Combustion Research
Research Profile: Taking Diabetes Research to Market

Consideration of Adding a Commercial Module to the International Space Station, J. Friefeld, D. Fugleberg, J. Patel, G. Subbaraman, Space Studies Board, The Boeing Company, 1999.

"The National Aeronautics and Space Administration (NASA) is currently assembling the International Space Station in Low Earth Orbit. One of NASA's program objectives is to encourage space commercialization. Through NASA's Engineering Research and Technology Development program, Boeing is conducting a study to ascertain the feasibility of adding a commercial module to the International Space Station. This module (facility) that can be added, following on-orbit assembly, is described. The facility would have the capability to test large, engineering scale payloads in a space environment. It would also have the capability to provide services to co-orbit space vehicles as well as gather data for commercial terrestrial applications. The types of industries to be serviced are described as are some of the technical and business considerations that need to be addressed in order to achieve commercial viability."

GEODE - Commercial Space Production Facility, Mark L. Holderman, 1999.

"The allure of utilizing External Tanks (ET) for on-orbit space platforms has existed for well over a decade. For this vision to be realized it must first be understood that the ET is already an integral element of a proven, validated and precisely balanced man-rated space delivery system. Excursions or departures from the certified (flight experience) design database, via extreme engineering changes to the baseline, must be avoided. Safety, predictable performance and the benefits of a successful Operations/Integration program are to be viewed as major accomplishments and not be subjected to unnecessary or potentially deleterious design perturbations."

ISS IN THE PRESS

The following are representative news and periodical articles that provide a variety of perspectives and opinions on the ISS, both pro and con.

Making Money in Space, Tim Beardsley, Scientific American, March 1999.

> *"Exploring the solar system turns out to be the easy part. The next great challenge will be creating profitable space enterprises.*
>
> *The International Space Station, if it is ever completed, will hold only seven crew members and generate negligible income, certainly not enough to cover its $40-billion construction cost. NASA still hopes to strike partnerships with companies interested in manufacturing in zero gravity; the agency is trying to sell research modules on the space station to pharmaceutical, biotechnology and electronics companies. But even NASA officials admit that commercial interest has been cool. So far the only space industry that has proved to be arousing success is the satellite communications business."*

ISS: The Flying Ham, Chris Bulloch, Interavia Business & Technology, January 1, 1999

> *"The world's space industry has cause to be glad of the International Space Station. Noone is asking the scientists what they think.*
>
> *The first two components of the International Space Station are finally in orbit -- the Russian (Khrunichev) - built and US-financed propulsion and power module 'Zarya', launched by Shuttle on December 3. Ironically, the Shuttle already had to carry up a spare battery for Zarya. It will now be virtually impossible to get the project cancelled."*

Castle in the Air?, Randolph Fillmore, Beagle, January 22, 1999.

> *"The International Space Station is up and running, although it will be more than a year before the biological research facilities are in place. There's still plenty of controversy over whether a space station is necessary or cost-effective for much of the proposed research."*

Lots of Money, Lost in Space; Station will mean lost opportunities on Earth, Jack Uldrich, Star Tribune, December 11, 1998.

> *"According to the National Aeronautics and Space Administration (NASA), 'the mission of the International Space Station is to enable long-term exploration of space and provide benefits to people on Earth.*
>
> *A laudable and worthy mission to be sure. Unfortunately, the International Space Station (ISS) is a $100 billion boondoggle that threatens the very mission it seeks to accomplish."*

10 Reasons Why This is a Winner: The Space Station's Place in History, Michael Martin-Smith, The Straits Times (Singapore), December 12, 1998.

> *"The foundation was laid for the $98-billion International Space Station with the docking of a Russian and a US module this week. Although the project will not stand up to a cost-benefits analysis just yet, Michael Martin-Smith, a British doctor and writer with a keen interest in space development, argues why it is important for our common future. Nearly 15 years after it was proposed by US President Ronald Reagan, the International Space Station project is finally underway, 400 km above our heads."*

Space is the Place, Martin Burkey, Arkansas Democrat-Gazette, November 29, 1996.

> *"A 17,000-mph chase ends with a slow-motion ballet and a remarkably gentle bump as a 115-ton spaceship glides silently through airless space and docks with a 507-ton space station. Deceptively simple in appearance, yet devilishly complex to execute, the International Space Station is a symbol of exploration much like the effort that created it."*

New Millennium, New Frontier, David Lore, The Columbus Dispatch, November 29, 1998.

> *"What did the witnesses feel when the Egyptians built the first pyramid or the Chinese laid the first stone of the Great Wall?*
>
> *Unless something goes wrong, the human race will pass another such milestone next Sunday as orbital assembly of the International Space Station begins."*

A Black Hole in the Sky, The Economist, November 14, 1998.

> *"Fourteen years and more than $20 billion after its conception, the first part of the International Space Station is about to be launched. Unfortunately, there is precious little for it to do once it is up there."*

Critics Praise NASA Plan to Privatize Space Station, Rick Tumlinson, Space Frontier Foundation, November 20, 1998.

> *"The Space Frontier Foundation praised a new plan by NASA to hand over operations of the International Space Station (ISS) to the private sector, and called for its immediate implementation. The "Commercial Development Plan for the International Space Station" recommends ISS be managed by a "non-governmental organization" to handle operations and deal with both government and commercial users of the facility, acting as landlord and station manager."*

Making Privatization Happen, Letter to the Editor Rep. Dana Rohrabacher, Space News, December 7-13, 1998.

> *"With the launch of the first two pieces of the international space station, America and its partners will be fully committed - in the sense of having jumped off the diving board - to the assembly and operation of the International Space Station. The only question will be whether we execute a pretty dive, or a costly and painful belly-flop."*

NASA Begins Countdown for Shuttle Launch That Will Put the First American Piece of the International Space Station in Orbit, Anchor Bob Edwards, Reporter Richard Harris, National Public Radio, December 1, 1998.

> *"The largest construction project in the history of space exploration is set to get underway this week. On Thursday, NASA plans to launch the first U.S. component of the international space station. Astronauts aboard the shuttle Endeavor will join the component to a Russian component already in orbit. Ultimately the orbiting facility is supposed to be as roomy as a 747 with enough living space for seven astronauts"*

Space Station Experiments have a Practical Payoff, John M. Shaw, The Plain Dealer, December 10, 1998.

> *"With the first assembly operation of the space station completed just a few days ago, now seems a good time to look again at what the space station will do for Americans, why we are building it and how Lewis Research Center will connect Cleveland to this tremendous scientific resource.*
>
> *The clear goal of the space station is a better standard of living for all Americans. That will come about, in part, because of research that will be done in a very special environment: sustained microgravity. By examining materials and processes in space, we will know how to make and do things better on Earth. And that's the main purpose of any research: to add usefully to the sum of human knowledge, thus improving the human condition."*

The Space Business Heats Up, Erick Schonfeld, Fortune, November 24, 1997.

> *"There is a new breed of entrepreneurs who think of space less as a scientific frontier than as a place to make money."*

Station Science Unprecedented, But Debate Will Rage On, Joseph Anselmo, Aviation Week and Space Technology, December 8, 1997.

> *"The scientific potential of the International Space Station is a point of great debate, but it is clear the project will provide the largest and most advanced space laboratory ever available to mankind. The amount of research on the station will be just a tiny fraction of that performed on Earth, but NASA says the microgravity environment on the facility could provide the key to unlock mysteries in areas such as biotechnology, combustion science and biomedical research."*

Science in the Sky, Tim Beardsley, Scientific American, June 1996.

> *"The International Space Station will be the most expensive object ever built. Although many scientists oppose the grandiose scheme, its political momentum now appears unstoppable.*
>
> *Commercial interest, too, is cool, even though the National Aeronautics and Space Administration has provided substantial incentives for businesses to conduct research and to manufacture high-tech products in space. To date, no large companies are planning major research or manufacturing efforts on the space station."*

The New Celestial Capitalists, Sharon Begley, Newsweek.

"With plans for floating spaceports, lunar rovers and missions to asteroids, business is viewing the heavens as the final (profit-making) frontier."

Global Space Station's 'Dawn' is Set to Rise, Richard C. Paddock, Los Angeles Times.

"The United States and Russia are preparing to launch the first piece of the most ambitious space project ever attempted: a multinational station that will take astronauts six years to assemble and will grow to nearly the size of two football fields."

APPENDIX B: LITERATURE REVIEW OF POTENTIAL ISS MARKET SECTORS

LITERATURE REVIEW OF POTENTIAL ISS MARKET SECTORS CONTENTS:

The contents of this appendix are focused on the various commercial sectors that might utilize some aspect of the ISS as a catalyst for other future commercial space activities. The documents listed in this appendix are neither intended to provide market forecasts nor to support a particular political position on the ISS. Rather, they are intended to give the reader a sense of the discussions that have taken place over the period of 1995 to present.

Brief summaries and/or abstracts of the following publications are provided as representative samples of the documentation reviewed and do not represent the entire body of work reviewed during the course of this study.

A number of the research areas that potentially could be conducted on the ISS do not have any documentation that met the criteria of the study parameters. This is not to say that the commercial potential of these research areas is non-existent, only that we were unable to find suitable documentation that focused solely on that particular research subject. Occasionally, publications are provided at the top level of specific topic areas because they may cover several or all of the various disciplines within that particular topic area.

In addition, several of the documents do not adhere strictly to our study guidelines but were noted due to their unique contribution to the overall report. The papers are presented in approximate reverse chronological order, from 1999 to 1995.

BIOTECHNOLOGY

BIOTECHNOLOGY CONTENTS:

- Tissue Engineering
- Pharmaceutical
- Agriculture

Description:

Biotechnology is a set of enabling technologies which allows the use of organisms or their cellular, sub-cellular or molecular components, to make products; or to modify plants, animals and microorganisms to carry desired traits.

The ISS R&D facilities provide an environment that could accelerate breakthroughs in biotechnology through research and production in microgravity. This section will be limited to covering the biotechnology disciplines identified in our review that could potentially benefit from research on the ISS, namely tissue engineering, pharmaceuticals and agricultural biotechnology.

NASA RESEARCH PLAN

"Biotechnology is the application of engineering and technology to life sciences research. Two primary areas of biotechnology will be researched on ISS: protein crystal growth and cell & tissue culturing. Protein crystal growth is essential in understanding the structure and function of proteins. Growing protein crystals in space allows some to grow larger and with greater perfection than Earth-grown ones. The larger molecular size and greater perfection makes determining their structure with x-ray diffraction much more effective. Once the structure is determined, the protein may be altered and/or synthesized in mass quantities. This process, called rational drug design, may produce more effective medicines while reducing side effects.

Growing tissue samples is one of the fundamental goals of biomedical research. Scientists use laboratory containers called bioreactors to culture samples of body tissues. Scientists could use cancer tumors and other tissues that are successfully grown outside the body to test and study treatments, such as chemotherapy, without risking harm to patients. These tissues from bioreactors will also offer important medical insights into how tissues grow and develop in the body. NASA engineers have already created breakthrough technologies for cell culture research on the ground. For example, NASA-developed bioreactors have already produced the first 80-day

lung culture, the first normal human intestine culture, and major advances in the quality of cancer tumor cultures. In the long term, tissues cultured outside the body may be used directly for replacing damaged tissues, treating diseases, or eventually replacing organs.

Shuttle astronaut Dan Bursch explains why growing crystals in space is important to us here on Earth:

"The National Institute of Health has said that protein crystal growth is the number one research tool that we'll be using in the next century... What happens here on Earth is that gravity actually distorts the shape of the crystal and actually ends up getting imperfections in it. What we can do in space is grow the crystals - most of the time grow them larger and in a more pure form - bring them back, and the larger crystal allows us to get a much better diffraction pattern out of the protein.

"The whole goal is to eventually synthesize the protein. There was a protein that I flew on one of my past flights called alpha interferon that's used in the treatment of cancer. The treatment has some bad side effects. If we understand the structure of the protein then we can alter the protein just so slightly and then synthesize it. We can make a whole new family of pharmaceuticals that can be used in the treatment of cancer, but without the bad side effects."

A Strategy for Research in Space Biology and Medicine in the New Century, Space Studies Board, National Research Council, 1998.

"The core of the National Aeronautics and Space Administration's (NASA's) life sciences research lies in understanding the effects of the space environment on human physiology and on biology in plants and animals…During the past decade there has been an explosion of new scientific understanding catalyzed by advances in molecular and cell biology and genetics, a substantially increased amount of information from flight experiments, and the approach of new opportunities for long-term space-based research on the International Space Station. A reevaluation of opportunities and priorities for NASA-supported research in the biological and biomedical sciences is therefore desirable."

Weightlessness and the Human Body, Ronald White, Scientific American, September 1998.

"The effects of space travel on the body resemble some of the conditions of aging. Studying astronauts' health may improve medical care both in orbit and on the ground..."

Global Cooperation Enhances Space Flight Research, Steve Bunk, The Scientist, June 8, 1998.

> *"Before the April 17 launch of Neurolab, the 16-day space shuttle Columbia flight during which 26 studies of the nervous system would be conducted, researchers differed in opinion concerning the microneurography experiment. Either a thin needle placed in a nerve just below the knee of an astronaut would show that electrochemical signals were being transmitted normally from brain to blood vessels via the autonomic nervous system, or the nerve activity would be greater in microgravity than on Earth, or it would decrease during space flight and the experiment wouldn't work at all...."*

Space Research May Accelerate Flu-Fighting Drug Development, Charles W Henderson, Tuberculosis & Airborne Disease Weekly, March 29, 1999.

> *"Even with vaccines, 20-40 million people in the United States catch the flu each year, and thousands are at risk of dying from its complications."*

> *"In the future, a new class of prescription drugs called neurominidase inhibitors offers the prospect for decreasing the duration and severity of the illness and may even prevent the development of symptoms in those exposed to the virus. One of these neurominidase inhibitors was developed through ground and space research conducted in partnership by NASA and the Center for Macromolecular Crystallography at the University of Alabama at Birmingham (UAB)..."*

Protein Crystal Growth in Microgravity: Status and Commercial Implications, Karen M. Moore, Marianna M. Long, Lawrence J. DeLucas, Space Technology and Applications International Forum - 1999.

> *"These experiments have successfully demonstrated that the low gravity environment can be used to produce crystals of proteins and other macromolecules that are superior to crystals of the same compounds grown on earth. Improved, extended x-ray diffraction data collected from space-grown crystals has contributed to the solution of the three-dimensional structures of many proteins and has augmented structure-based drug design studies targeting several diseases and degenerative conditions."*

The BioDyn Facility on ISS: Advancing Biomaterial Production in Microgravity for Commercial Applications, Niki Myers, Francis Wessling, Mark Deuser, C.D. Anderson, Marian Lewis, Space Technology and Applications International Forum - 1999.

> *"The primary goals of the BioDyn program are to foster use of the microgravity environment for commercial production of bio-materials from cells, and to develop services and processes for obtaining these materials through space processing."*

Potential Commercial Use of the International Space Station by the Biotechnology/Pharmaceutical/ Biomedical Sector, George Morgenthaler, Louis Stodieck, Space Technology and Applications International Forum - 1999.

> *"The International Space Station (ISS) is the lynch-pin of NASA's future space plans. It emphasizes scientific research by providing a world-class scientific laboratory in which to perform long-term basic science experiments in the space environment of microgravity, radiation, vacuum, vantage-point, etc. It will serve as a test-bed for determining human system response to long-term space flight and for developing the life support equipment necessary for NASA's Human Exploration and Development of Space (HEDS) enterprise. The ISS will also provide facilities (up to 30% of the U.S. module) for testing material agricultural, cellular, human, aquatic and plant/animal systems to reveal phenomena heretofore shrouded by the veil of 1-g. These insights will improve life on Earth and will provide a commercial basis for new products and services."*

State Native's Work Flies, Karen Klinka, The Sunday Oklahoman, November 1, 1998.

> *"Dr. Daniel Carter, 44, created the Protein Crystallization Apparatus for Microgravity, or P-CAM, a high-capacity crystal growth unit housing 378 viral experiments..."*

Making Space on Earth: Researchers Stimulate Microgravity to Study Cells, Viruses, Mark Somerson, The Columbus Dispatch, November 6, 1998.

> *"Armed with NASA funds and high-tech equipment, researchers John Hughes and Jim Long are mimicking zero-gravity conditions to grow cells into three-dimensional tissue - a method that allows scientists to observe life's building blocks in a whole new light..."*

NASA picks 48 Researchers for Biotech Work in Microgravity, Aerospace Daily, December 21, 1998.

> *"NASA has picked 48 researchers to share about $33 million worth of grants for microgravity biotechnology research in such areas as protein crystallization, cell science and new technology development that could lead to new designer drugs, "tissue engineering" and new biosensors..."*

Drug Development NASA Research Helps Map Protein Structures, Tuberculosis & Airborne Disease Weekly, September 28, 1998.

> *"Research sponsored by the National Aeronautics and Space Administration (NASA) Microgravity Research Program at Marshall Space Flight Center, is making significant contributions to scientists' understanding of the molecular structure of living things - a key to the development of new disease-fighting drugs."*

Research drought looms after Neurolab mission; no further flights scheduled for Spacelab program, Andrew Lawler, American Association for the Advancement of Science, April 24, 1998.

> *"Museums in Washington, D.C. and Bremen, Germany, are already preparing to display segments from the first reusable laboratory in space, now orbiting Earth as the Neurolab mission aboard the space shuttle Columbia. Neurolab is the last scheduled flight in the 15-year-old Spacelab program, and its demise threatens to turn the business of conducting lab experiments in space into a museum piece as well: Over the next few years, until the yet-to-be-built international space station is ready for use, opportunities for such research will be few and far between.*
>
> *"It's an absolutely major problem," says Mary Jane Osborn, a biologist at the University of Connecticut, Farmington, who also chairs the National Research Council's space biology panel. "If there are no flights for 5 years, the community is going to evaporate." That worry is shared by Europeans, who spent more than $1 billion to build Spacelab. "It's a very grave danger," says Guenther Seibert, chief of the European Space Agency's microgravity and space station utilization effort. "NASA doesn't have money for more Spacelab missions, and we don't have money for new payloads." NASA insists it can cobble together enough flight opportunities to tide researchers over until the station is ready. In the meantime, a debate rages over whether such expensive flights provide good scientific value for the money.*

A major stumbling block for conducting experiments in space, however, is money. Crewed missions are notoriously expensive -- about half a billion dollars per shuttle flight. "It's costly as hell," says Simon Ostrach, a materials scientist at Cleveland's Case Western Reserve University who has flown experiments on Spacelab. "I'm not sure any scientist would say it's worth the cost of shuttle flights." Still, he adds, costs are relative. "Physicists, for example, use some pretty expensive facilities, too." Robert Park, a physicist at the American Physical Society, notes that Spacelab-related research is probably the costliest in history. "Some of the science is probably worth doing, but there is a lot of science we don't do because it costs too much."

NASA Biotech Spinoff Seeks Commercial Operation on Station, Aerospace Daily, November 11, 1997.

"Cry-X Inc., a biotechnology startup spun off from the NASA-backed Center for Macromolecular Crystallography, is developing business plans and hardware for a commercial protein crystal unit on the International Space Station that would charge pharmaceutical companies "user fees" to create tiny building blocks for drug research in space."

TISSUE ENGINEERING

Description:

This area of space research shows particular promise in the treatment of diseases such as aging, degenerative diseases, burns, blood and lymphoid disorders, structural tissue deficits and vital organ failure.

On Earth, in-vitro tissue growth is typically accomplished by seeding organ-specific cells onto biodegradable, three-dimensional, scaffold in a bioreactor that simulates the environment in the body. The cells attach, divide and secrete extra-cellular matrix proteins and growth factors, forming functional tissue. In-vivo tissue growth is typically performed by performing the above in a living host or by injecting growth factors to promote the host's own cell growth. Other current application areas include:

- Cells combined with biomaterials and active substances
- Isolated cells used for implantation
- Biomaterials-based scaffolds for the growth of new tissue
- Tissue engineered small-diameter vascular grafts that could be used as a viable alternative to coronary bypass surgery
- The administration of active substances to affect endogenous tissue
- Connective tissue
- Inter-vertebral discs
- The replacement of aged muscle
- The replacement of aged corneas.

Tissue Engineering in Microgravity: Potentials for Biotechnology within the Applications Promotion Programme of the European Space Agency, Roger A. Binot, ESA, ESTEC.

> *"Experimental data obtained in microgravity conditions aboard spacecraft or during ground microgravity/hypergravity simulation studies indicate a change in cell function related to the gravity level."*

PHARMACEUTICALS

Description:

Pharmaceuticals research may be broken down into four key focus areas for ISS-related microgravity research. These are pharmaceutical preparations, medicinals and botanicals, biological products and diagnostics.

Structure-based drug design technology, also called rational drug design, a method that relies on protein crystal growth and x-ray crystallography, is becoming an integral part of the drug development process. Analyzing such crystals, using X-ray crystallography, is the best way to understand their structure. From this, scientists can determine how bacteria, viruses and our own bodies work and how best to design drugs to cure disease.

During the course of our research we found no publicly available reports that specifically address the paid commercial utilization of the ISS for research based on the criteria established for this study.

AGRICULTURE

Description:

Agricultural biotechnology comprises a multitude of research areas that may lead to development of new agricultural processes and plant species as well as new chemicals and other critical materials. When applied to the field of agriculture, the benefits are enhanced production, increased nutritional quality and higher disease resistance of crops and animals.

Microgravity May Enhance Gene Transfer in Plants, SpaceDaily, April 27, 1999.

> *"Transferring desirable genes into crops is a high-tech game of chance, with success rates running about 1 in 1,000. But the odds get a whole lot better, it seems, when you remove gravity from the mix.*
>
> *An industry-sponsored research project aboard the Oct. 29 NASA Space Shuttle suggests that microgravity might enhance genetic engineering of plants. The project, coordinated by UW-Madison's Wisconsin Center for Space Automation and Robotics (WCSAR), tested a unique technology that uses bacteria as a means for gene transfer."*

Zero-Gravity Soybeans Could Be Medicinal, Jenni Laidman, Press Journal, April 18, 1999.

> *"If you think soybeans are good for you now, just wait until space-grown soybeans hit the market.*
>
> *Stephen L. Goldman, the director of the Plant Science Research Center at the University of Toledo, is part of a team that sent soybeans on the space shuttle Oct. 29 with Sen. John Glenn. The group wanted to see how a genetic engineering technique designed by Goldman and researcher Anne Graves behaved in weightlessness."*

IFF Tests Fragrance in Space, Soap and Cosmetics, January 1999.

> *"Aboard the NASA Space Shuttle mission STS-95 that lifted off on October 29, 1998 was an unusual passenger -- a miniature rose plant. International Flavors & Fragrances, Inc. (IFF) along with the Wisconsin Center for Space Automation and Robotics (WCSAR), at the University of Wisconsin, Madison, conducted a pioneering experiment during the Shuttle's flight to examine the effects of microgravity on the production of fragrance."*

SPACE TECHNOLOGY TESTBED

SPACE TECHNOLOGY TESTBED CONTENTS:

- Satellite Technologies
- Tether Technologies
- Space Solar Power
- Satellite Servicing

Description:

The space technology testbed sector describes using the ISS to test technologies that can be utilized for applications in traditional and emerging space markets. In order to analyze and improve upon the technical aspects of systems and subsystems, or to provide proof of concept testing to conduct R&D in the LEO environment provided by ISS.

Advanced Space System Concepts and Enabling Technologies for the 2000 to 2030 Time Period, by Ivan Bekey for the Aerospace Corporation, 1998.

> This report updates a similar report done by Mr. Bekey in 1976, discusses technologies concepts that apply to NASA, DOD, NRO and commercial interests that could be developed in the 2000-2030 timeframe. The approach taken for this research was wide open with essentially no limiting factors that would preclude any concepts from being evaluated. This document provides a very comprehensive discussion of what is possible in the space arena.

Space Manufacturing 11 The Challenge of Space: Past and Future, Conference Proceedings from the 13th SSI/Princeton Conference on Space Manufacturing, Space Studies Institute, 1997.

> This publication contains numerous papers on the topics of; Asteroids and Nonterrestrial Materials, Transportation and Structures, International, Legal and Economic Considerations, Wireless Power Transmission, Biomedical Considerations and Robotics.

Space Manufacturing and Processing, by the U.S. Dept. of Commerce Office of Air and Space Commercialization, 1996.

This publication discusses the possibilities of developing new materials in space, biotech applications, agricultural applications, the disposal of nuclear waste, space solar power, tourism and other potential commercial space based activities. It also provides discussion of how the ISS, external tank based business parks and the GOEDE project could support and foster the development of such business activities in space.

Space Manufacturing 10 The Challenge of Space: Past and Future, Conference Proceedings from the 12th SSI/Princeton Conference on Space Manufacturing, Space Studies Institute, 1995.

This publication contains numerous papers on the topics of: Transportation, Asteroids and Nonterrestrial Materials, Biomedical, Robotics, Advanced Technologies, Wireless Power Transmission, International, Legal and Economic issues.

SATELLITE TECHNOLOGIES

Description:
Using the ISS as a testbed to advance technology for communications and remote sensing spacecraft through the development, characterization and validation of spacecraft technology. Using the ISS, satellite technology developers can focus their efforts on the components of interest as opposed to financing, designing, building, integrating and launching tech-demo satellites just to test a specific piece of new space hardware. Additionally, ISS technology development experimenters will have a virtual presence throughout the course of a demonstration, with the possibility of retrieving their hardware for post-test evaluation.

An Engineering Research Testbed for Photovoltaic, Geoffrey A. Landis and Andrew Sexton from the Ohio Aerospace Institute and NASA Lewis Research Center, 1999.

> *"The Ohio Aerospace Institute and the NASA Lewis Research Center are designing and building a solar-cell calibration facility, the Photovoltaic Engineering Testbed (PET) to fly on the International Space Station to calibrate, measure and qualify advanced solar cell types in the space environment. PET will serve three primary functions: calibration, measurement and qualification of solar cells, in order to bring new solar cell technologies to spaceflight readiness."*

Engineering Research and Technology Development on the Space Station, National Research Council, 1996.

> The report discusses the potential for using the ISS as a platform for Engineering Research and Technology Development (ERTD) for conducting tests on materials and systems that must operate in space.
>
> The chapter descriptions from the preface are as follows:
>
> *"Chapter 1 defines ERTD and identifies the principal issues explored in the report. In Chapter 2, the kinds of ERTD that could most appropriately be performed on the ISS are discussed, and a method for setting priorities is proposed. A detailed assessment of the individual fields of research examined by the committee is contained in Chapter 3. Chapter 4 reviews the interface between the space station program and university and industrial experimenters and offers recommendations for facilitating ERTD by these external stakeholders. Chapter 4 also investigates ISS instrumentation, generic facilities and other hardware needed to support ERTD*

research. The committee reviewed techniques for assessing the benefits of research to U.S. competitiveness but found, as is discussed in appendix B, that none could satisfactorily predict benefits for ISS ERTD. In an effort to provide NASA with more than a negative finding, however the committee in Chapter 5 suggests steps that NASA could take to improve the likelihood that ERTD on the ISS will benefit the economy."

TETHERS

Description:

Tether technology uses cables made of high-strength fibers such as Spectra, Zylon, or Kevlar to conduct various functions such as propulsion, space debris removal and power generation. Tethers made of conducting materials can also be used to interact with electric and magnetic fields in space, allowing propellantless propulsion of LEO spacecraft. Tethers are also being considered for use with the Space Shuttle and the ISS for raising or lowering payloads and as a means to reboost the ISS by utilizing the space shuttle during the course of its lifetime.

Tethers Unlimited Inc. Newsletter, April 1999.

- *TUI has also teamed with Boeing and the University of Maryland to complete a Phase I study for the NASA Advanced Concepts Office to work on a Hypersonic Airplane Space Tethers Orbital Launch System (HASTOL).*
- *This award was just awarded in April of 1999.*
- *TUI has also formed a wholly owned subsidiary, Deorbit Inc. to develop the Terminator Tether™ that is being marketed as a system for deorbiting satellites.*
- *Deorbit Inc. has received a $600,000 SBIR Phase II contract for this project and is still looking for investors to raise the additional $3.5 million that is required per their business plan.*
- *Deorbit Inc. has also received endorsement letters from Lockheed Martin, Teledesic and Ellipso as potential users of the Terminator Tether™ system.*
- *Deorbit Inc. is currently finalizing the patent process for 13 tether technology related patents.*

Tether Transport From Sub-Earth-Orbit to the Lunar Surface-and Back!, Robert P. Hoyt and Robert L. Forward of Tethers Unlimited Inc. presented at the International Space Development Conference, 1997.

"Systems composed of several rotating tethers may provide an economic means of exchanging payloads between the Earth's upper atmosphere and lunar bases with little or no propellant required. The underlying concept is to use long rotating tethers to throw payloads to the Moon and to catch return payloads sent from the Moon. By transporting equal masses to and from the Moon, the total energy and momentum of the system can be conserved. Because the mass of a rotating tether increases dramatically with the DV it can impart to a payload, splitting the lunar transfer boost operation up into two or more stages is necessary to reduce the required tether mass to reasonable levels. This work develops analytical methods for calculating designs for

staged tether systems capable of repeatedly exchanging payloads between sub-Earth-orbit and bases on the lunar surface. By properly choosing the design of the system, the total Earth-orbit mass required for a tether system to throw payloads to the Moon, using currently available materials, can be less than ten times the payload mass."

Applications of the Terminator Tether™ Electrodynamic Drag Technology to the Deorbit of Constellation Spacecraft, Robert P. Hoyt, Robert L. Forward of Tethers Unlimited Inc. and Chauncey Uphoff of Fortune-Eight Aerospace Industries, Inc. presented at the Tether Technical Interchange Meeting, 1997.

"The Terminator Tether™ is a small, lightweight system that will use passive electrodynamic tether drag to rapidly deorbit spacecraft from low Earth orbit. Studies of the application of electrodynamic drag to the deorbit of constellation satellites indicates that the Terminator Tether™ offers significant mass savings compared to conventional rocket-based deorbit systems. Moreover, because it uses passive electrodynamic drag to achieve deorbit, it can deorbit the spacecraft even if the host has lost power and control functions. Numerical analyses of the performance of the Terminator Tether™ indicate that a five to ten km long conducting tether weighing only 2% of the host spacecraft mass can deorbit a typical constellation satellite within a few months. Although the tether increases the total collision cross-sectional area of the satellite system during the deorbit phase, the electrodynamic drag is so many times greater than atmospheric drag at constellation altitudes that the tether can reduce the collisional Area-Time product for the satellite by several orders of magnitude. The Terminator Tether™ thus can provide a low-cost and reliable method of mitigating the growth of debris in valuable constellation orbits."

SPACE SOLAR POWER

Description:

The concept of Space Solar Power (SSP) has been written about, formally studied and debated since the 1970's by numerous organizations and individuals. The concept was originally developed by Peter Glaser, driven primarily by the energy crisis of the time. His design utilized numerous satellites as a means of collecting the sun's energy to be beamed as microwaves to a ground station and then distributed through the existing electrical system. Since that time, there have been many additional system architectures introduced and much discussion regarding the concept.

Space Solar Power: A Fresh Look at the Feasibility of Generating Solar Power in Space for use on Earth, by Science Applications International Corporation, Futron Corporation and NASA, 1997.

> This study discusses the energy markets and issues related to the economics facing the potential development of this technology, several candidate SSP systems and then provides a model for evaluating demand, revenues, performance and costs for the systems. The study also provides several white papers on issues relevant to SSP.

The Promise of Reusable Launch Vehicles for SPS, by Patrick Collins and H. Taniguchi, 1997.

> *"Since the US Department of Energy finished its SPS Concept Development and Evaluation Program in 1981, research on satellite solar power stations has received very little funding from energy research organizations around the world. The main reason for this has been the perception that electricity delivered to Earth from orbiting solar power stations would be too expensive, due to the very high cost of space activities. During the 1990s work within the space industry on developing reusable launch vehicles in order to sharply reduce launch costs has grown considerably. Since the cost of space activities depends primarily on the cost of access to space, this is very encouraging for the prospects of SPS systems. The potential implications of this work for both near-term SPS pilot plants and longer term commercial SPS systems are discussed."*

An Approach to Develop Space Solar Power as a New Energy System for Developing Countries, by Makoto Nagatomo, 1996.

> *"There are many concepts of space solar power systems that have been proposed for space solar energy to be used for humankind. However, most of them were theoretical and not evaluated on*

the basis of becoming practical power systems. The SPS 2000 study was made on practical assumptions and has indicated a realistic approach to space solar power research which can be interpreted as follows:

- *To facilitate research on this power system as a future energy source to compete with other sustainable energy candidates, it is necessary to consider the space solar power system as a variation of solar power systems now under research and development for terrestrial use.*
- *The advantage of space solar power over terrestrial solar systems is one order of magnitude larger solar power in space than on the earth. The disadvantage is the high cost of transportation of the required facilities to space. Even if reusable space transportation systems under development realize lower costs, the advantage over terrestrial systems is expected to be marginal. A cost target is therefore mandatory for engineering space solar power stations. The microwave "fuel" concept can be applied to this case too.*
- *It is practical to apply the concept of microwave "fuel" as the interface between space power suppliers and buyers, as utility power suppliers and consumers are related to each other by the standard of commercial electric power. Considering that a properly selected microwave frequency makes it possible for users to plan and even build their rectennas, I strongly recommend the use of 2.45 GHz as a standard for wireless power transmission."*

Beam it Down: How the New Satellites can Power the World, Martin I. Hoffert and Seth D. Potter of NYU and Boeing

This paper describes how Solar Power Satellites (SPS) could be used to provide energy for the world. The authors suggest utilizing the microwaves from the communications satellites that are going to be in service over the next few years to transmit and receive power while utilizing the same infrastructure. The paper then goes on to discuss the potential demand for space solar power (SSP), some beneficial characteristics of SSP and the lack of funding in the U.S. as well as the enthusiasm being given the concept by the Japanese. The next section acknowledges that launch costs are too high and offers some suggestions for mitigating the problem. The final section of the paper suggests some other obstacles to and advantages of SSP technology.

A Few Things You Occasionally Wanted to Know About Wireless Power Transmission, by Seth Potter

"The design of Solar Power Satellites or a Lunar Power System (LPS) involves beaming energy to Earth, perhaps in the form of microwaves. Unfortunately, the magnitude of such projects has discouraged the planning of demonstrations. In order to understand the physical requirements that tend to push the size of a space power system upward, it is necessary to consider the physics of wireless power transmission, or power beaming."

SATELLITE SERVICING

Description:

Satellite servicing concepts are being studied and tested to provide maintenance and repair services for in-orbit satellites. Potential services provided could consist of fixing problems that arise during various stages of the satellites life, make improvements to the spacecraft by changing components or to add fuel to extend the useful life of the spacecraft. Most of the efforts regarding this topic are still being conducted by government agencies.

A Concept for Cost-Effective, Satellite Servicing, Richard W. Madison of Air Force Research Laboratory, 1999.

> *"Air, land and sea vehicles are routinely serviced to increase their availability, flexibility, capability and life span. Servicing could extend the same benefits to satellites, but is rarely employed because current methods are cost effective only for very expensive satellites. This paper presents a concept to minimize the cost of satellite servicing. It combines requirements for a next-generation of serviceable satellites, with an infrastructure whose cost can be amortized over many servicing missions. This should make servicing cost effective for a wider range of spacecraft."*

Supplement to On-Orbit Servicing of Space System, by Donald M. Waltz and Hans F. Meissinger, 1998.

> This update to the original publication published in 1993 provides updates to the recent Hubble Space Telescope servicing missions, new technology developments derived from those missions and plans for future Hubble and other missions. The relevance of ISS commercial activity that can be implied from this document is, that the extensive amount of knowledge, training and technology development that has been gained from the MIR missions and will be gained during the ISS assembly process may contribute to commercial satellite servicing operations at some point in the future.

MATERIALS AND PROCESSES

MATERIALS AND PROCESSES CONTENTS:

Description:

Materials science investigates the relationships among the structure, properties and processing of materials. It is not an industry category nor could it be characterized as a market in and of itself. Materials research is an activity conducted on behalf of numerous industries and serves many purposes. Materials research focuses on improving upon existing materials, creation of new materials, and the improvement upon current or the creation of new processes for their manufacture or use. Microgravity materials scientists seek to use microgravity to study the processes by which materials are produced and the relationships between the formation of a material and its properties. One such method uses containerless processing which eliminates impurities and stresses that are realized when the material comes in contact with container walls.

Processes research is aimed at determining and improving upon various physical phenomena that are key to many NASA missions and industrial business activities. Like materials research, processes research can be applied to a number of industries for many different purposes.

Materials Development Opportunities, Charles A. Lundquist of The Consortium for Materials Development in Space at the University of Alabama Huntsville, 1999.

> *"Commercial materials development opportunities on the International Space Station have been the subject of extensive discussions over many years. Most of these have addressed specific examples. However, this discipline is reaching a level of maturity such that a more penetrating analysis of space opportunities is timely. A categorization is presented that first identifies three classes of results and second notes four economic traits. Each specific development opportunity can be placed in a matrix position dictated by the class of its results and by its economic trait."*

Space Product Development Experiment Module Utilizing the ISS, Christine Watson, Charles Lundquist, Francis Wessling, James Smith and Robert Naumann of The Consortium for Materials Development in Space at the University of Alabama Huntsville, 1999.

> *"Furnace facilities for materials processing on the International Space Station (ISS) will include the Space Product Development Experiment Module (SPDEM) which includes a transparent Furnace Module and an opaque Furnace Module. The SPDEM is scheduled currently for UF-3 aboard the Materials Science Research Rack (MSRR). Various commercial interests can be satisfied sequentially by scheduled employment of the SPDEM. The CMDS will be the facility manager through whom arrangements can be made for SPDEM access. The ISS should provide long growth periods which are needed to grow large single crystals in microgravity. A typical area of commercial interest is acousto-optic filters (AOTF), based on mercurous halide research which would continue on the ISS, research begun on the STS-77 mission. Another area of commercial interest planned for implementation on ISS is liquid metal sintering of composites to further improve techniques for making better quality materials."*

Levitating Furnace for Micro-G on ISS, Spacedaily, 1999.

> This news article discusses a levitating furnace facility called TEMPUS that was created by the German Space Agency. This facility is designed to conduct containerless research for metals and alloys. It has been flown on MSL-1 and IML-2 and has provided highly consistent data which is valuable for this type of research.

Promise of True Holographic Projection, Spacedaily, 1999.

> This new article discusses a Hungarian materials research furnace that may end up on the ISS. The Universal Multi-Zone Crystallizator can be used for semiconductor, laser and optics research.

Engineering Competitive Materials, James C. Williams, The Bridge 1998.

> This paper discusses the use of computational and analytic tools to conduct materials and materials processing research. The process and requirements for discovering new materials is also outlined.

Revolutionary Microgravity Processing Capability is Goal of new Joint Venture; SPACEHAB and Guigne Technologies Perfecting "Containerless" Processing Method, SPACEHAB, 1998.

This press release discusses the joint venture between the two companies to develop, manufacture, market and sell the service of the Space-DRUMS facility. The new facility for use on Shuttle and ISS can be used for alloy, semiconductor, glass and ceramics, crystal growth and fluid physics research.

Future Materials Science Research on the International Space Station, National Research Council, 1997.

This NASA requested study discusses several issues regarding the ISS's Space Station Furnace Facility (SSFF) Core. The study was to (1) examine NASA's research plan for high-temperature, microgravity materials science; (2) assess the ability of the current SSFF Core concept to support the range of high-temperature experiments and associated specialized furnaces; (3) evaluate the usefulness of the planned high-temperature microgravity materials-science projects and developed technologies to the research and industrial materials-science communities in terms of already identified need and planned activities through the year 2010; (4) assess the ability of NASA's high-temperature microgravity materials-science plan to accommodate evolving interests and priorities in the field of materials science; and (5) examine the procedures used by NASA to select experiments for the ISS and determine if they encourage active participation by the broader materials-science research community.

Findings and recommendations of the study:

- Need to improve or create new systems to handle g-jitter.
- Provide more information to potential researchers regarding the SSFF Core concept.
- System design should not be the characteristic that determines which programs get selected but rather those that benefit science, technology, engineering and society in general.
- NASA should ensure that perceived flight availability does not influence the initial proposal review portion of the process.
- The microgravity materials-science program must be proactive in developing an effective outreach program to encourage more proposals from disciplines that currently are under represented.
- The SSFF Science Working Group (SWG) should be comprised of individuals with

expertise in all materials subjects. Protocols to ensure objectivity and independence of SWG members should be created.

- The SSFF should be modified to allow for a greater range of materials science programs.
- More focus should be given to polymeric, glass and ceramic materials research.

ELECTRONIC AND PHOTONIC MATERIALS

Description:

Electronic materials are used to transmit signals by way of electrons. Manufacturers are beginning to reach the physical limits of what they can do with ordinary silicon-based materials, and as a result are regarded as an area that could be improved by study in microgravity (e.g., new areas of fabrication such as molecular beam epitaxy, or new semiconducting materials). Many large corporations, industry consortiums and government agencies are conducting terrestrial research in the area of semiconductors.

Photonics is the optical equivalent of electronics, and the two technologies coexist in such innovations as optoelectronic integrated circuits. Photonic applications include data storage such as optical disks and holograms, data transmission such as fiber optics, cell phones and pagers. Photonic materials such as Gallium Arsenide, Silicon Germanium and Silicon Carbide are examples of compounds being used to improve the capability of semiconductors. Scientists and engineers are working to combine photonics with other technologies to facilitate growth of the economies' largest growing industry information technology. Continued development of information technologies is dependent on the integration of photonics and electronics.

Semiconductor Materials Research Needs for the 21st Century, Paul S. Peercy of SEMI/SEMATECH, The Bridge, 1998.

This paper discusses the current trends in the semiconductor industry and the requirements for improving the materials that are used to manufacture products such as integrated circuits (IC). The discussion focuses on, silicon-based ICs. Mr. Peercy notes that in 1997 $2 billion was spent on materials for semiconductors in the U.S. An industry driver behind the need for material research in this area is the need to make products smaller and faster. In order to meet the demand for smaller and faster products new manufacturing techniques will be required and new materials to manufacture with thus the need for research in this area.

CERAMICS

Description:

Ceramic materials are made from nonmetallic inorganic minerals. Ceramics are noted for their lightweight, hardness, and resistance to corrosion and high temperatures. Glass is one of the most basic of ceramic materials. It is the only material that is transparent, resistant to heat, and able to hold a vacuum inside all at the same time.

Most ceramic synthesis and processing is done at high temperature either by solid-state processes exclusively or by processes in which there are only small amounts of viscous liquid phases. Because the microgravity environment is more important in systems that contain liquids, microgravity research in ceramics tends to be less prominent than in other materials areas.

Applications for ceramics include:

- Aircraft and automotive engine components
- Gas turbine components
- Thermal protection systems
- Hot gas filters and radiant burners
- Fiber optics for telecommunications
- Scaffoldings for tissue growth
- Composite structures
- Electronics
- Prosthetics and other medical applications
- Thermal, electrical, environmental and ballistic insulation
- Environmental cleanup and filters
- Joints and bearings

Recent Microgravity Results in the Synthesis of Porous Materials, X. Zhang, D.P. Johnson, A.R. Manerbino, J.J. Moore, and F.D. Schowengerdt, 1999.

> *"Porous ceramics produced by reaction synthesis can be engineered to meet the strength and porosity requirements of a consumer, such as for the application of bone replacement materials. Control parameters such as ambient pressure, dilutents, green density, gasifying agents and gravity can be used to effect desired product properties to mimic those same properties of natural bone, enabling growth into the implant."*

Porous Ceramics Preliminary Technology Transfer Assessment, Colorado Venture Centers Inc., 1998.

The Colorado Venture Center (CVC) on behalf of the Colorado School of Mines Center for Commercial Applications of Combustion in Space conducted this preliminary assessment to analyze the potential for ceramic products synthesized by using self-propagating high-temperature synthesis. The two primary applications discussed were for filters and catalyst substrates and bioceramic medical applications.

The Potential of Advanced Ceramics, Roger G Ackerman, CEO of Corning Inc., 1997.

This speech given to the United States Advanced Ceramics Association discusses some of the issues regarding the early development of fiber optics and automobile catalytics. He goes on to discuss new areas of interest such as lenses made from fused silica that are used to manufacture semiconductors, glasses for large telescope mirrors, filters and oxidizers and newer catalytic materials. Mr. Ackerman suggests that given time advanced ceramics will be beneficial to many industrial applications and societal problems.

METALS AND ALLOYS

Description:

Traditional metals include commodity alloys of elements such as iron, nickel, and aluminum. Advanced metals tailored for specialty application include lightweight magnesium alloys; specialty tool steels and nickel-based alloys; refractory alloys; and high-temperature, high-strength inter-metallics.

During the course of our research we found no publicly available reports that specifically address the paid commercial utilization of the ISS for research based on the criteria established for this study.

POLYMERS

Description:

Polymers are large molecules consisting of long chains of repeated units. Polymers potentially represent the broadest classes of engineered materials, permitting great innovation and precision in design down to the molecular level. Polymers are noted for unique combinations of properties and have a range of applications, from plastic containers to liquid crystal displays. Plastic wrap and Kevlar bulletproof vests are some common examples. Polyimides are advanced, high-temperature polymers used for electronic packaging and aircraft skins.

During the course of our research we found no publicly available reports that specifically address the paid commercial utilization of the ISS for research based on the criteria established for this study.

COMBUSTION

Description:
Combustion science aims to improve the understanding of the fundamental energy transformation process and gain new insight into its physical dynamics. By better understanding the fundamentals of combustion, researchers may develop more accurate models, leading to increased efficiencies in commercial applications.

Space enables the collection of the measurements needed to understand and resolve practical combustion problems. These measurements are most easily made on large, steady, slow-moving, and symmetric flames that provide good time and space resolution. These simplified flames are not present on Earth because convection cause flames to take on their characteristically elongated shape.

Commercial Combustion Research Aboard the International Space Station, F.D. Schowengerdt of the Center for Commercial Applications of Combustion in Space at the Colorado School of Mines, 1999.

> *"The Center for Commercial Applications of Combustion in Space (CCACS) is planning a number of combustion experiments to be done on the ISS. These experiments will be conducted in two ISS facilities, the SpaceDRUMStm Acoustic Levitation Furnace (ALF) and the Combustion Integrated Rack (CIR) portion of the Fluids and Combustion Facility (FCF). The experiments are part of ongoing commercial projects involving flame synthesis of ceramic powders, catalytic combustion, water mist fire suppression, glass-ceramics for fiber and other applications and porous ceramics for bone replacements, filters and catalyst supports. Ground and parabolic aircraft-based experiments are currently underway to verify the scientific bases and to test prototype flight hardware. The projects have strong external support."*

Money in Microgravity, Aerospace Daily, 1997.

> This article references the Ring Flame Stabilizer researched by scientists while on board the Space Shuttle. The stabilizer increases home furnace efficiency by 2% while cutting oxide emissions by a factor of 10.

FLUID PHYSICS

Description:

The behavior of fluids is fundamental to many phenomena in materials science, biotechnology, and combustion science. For instance, the performance of power plants depends on the flow characteristics of vapor-liquid mixtures. Oil recovery from partially depleted reservoirs depends on how liquids flow through porous rocks. The safe engineering of buildings in earthquake prone areas requires an understanding of fluid-like behaviors of soils under stress.

Many of our intuitive thoughts about fluids do not hold up in orbit because of forces that are normally masked by gravity, such as surface tension, control fluid behavior in microgravity. For example, surface tension causes drops to form spheres in zero gravity. Differences in fluid behavior offer scientists and commercial researchers unique opportunities to explore different aspects of the physics of fluids.

During the course of our research we found no publicly available reports that specifically address the paid commercial utilization of the ISS for research based on the criteria established for this study.

ENTERTAINMENT

ENTERTAINMENT CONTENTS:

- Sound Stages
- Space Athletic Events
- Space Tourism
- Space Theme Park

Description:

The entertainment industry will play an important role in raising worldwide awareness of the ISS. A large percentage of the world's population is not currently aware of the existence of the ISS, let alone its function and role. Based on the number of recent films based on space reality, it is likely the ISS will appear in numerous films, television, print media and internet events. The role of ISS in this field will be as the hub of space-theme entertainment (e.g., a featured location).

The three most probable domestic entertainment industries in a position to involve the ISS in their content are television, motion pictures and internet. The first two sectors dominate the creation and distribution of entertainment content consumed worldwide. The internet, however, is becoming an increasingly popular distribution pipeline for both passive entertainment content as well as interactive content.

SOUND STAGES

Description:

The on-orbit sound stage would be developed based on the need of earth-bound entertainment and other content creation firms to film sustained and believable live action microgravity scenes. While capabilities of the digital special effects industry have come a long way in the last several years, it is still extremely difficult to generate digital special effects which accurately mimic a live human actor in microgravity.

External shots of deep space, the celestial bodies, the planets in the solar system create excellent sources of stock footage for print, films, internet, and television drama and news. This stock footage can be used as either backdrop or the raw data for digital special effects.

IMAX Corporation Home Page

BLUE PLANET (1990: 42 Minutes)

A presentation of the Smithsonian Institution's National Air and Space Museum and Lockheed Martin Corporation, in cooperation with the National Aeronautics and Space Administration. Filmed in space by the Astronauts. Produced by Graeme Ferguson, IMAX Space Technology Inc., for the Smithsonian Institution's National Air and Space Museum and Lockheed Martin Corporation. Principal Director: Ben Burtt. Writer, Editor and Narrator: Toni Myers.

Blue Planet, a space film about Earth, gives us an experience of our home planet that, until now, has only been shared by astronauts. Spectacular scenes from space, filmed aboard several space shuttle missions, are intercut with scenes of the Earth's surface, clearly showing the powerful forces that affect our planet. Volcanoes, earthquakes and typhoons are depicted--but it is the signs of pollution, ozone depletion, deforestation and energy consumption as seen from space that reveal the more disturbing human impact. The Washington Post says, "If a picture is worth a thousand words, any one scene from Blue Planet is worth a zillion."

MISSION TO MIR (1997: 40 Minutes)

IMAX Corporation and Lockheed Martin Corporation in association with the Smithsonian Institution's National Air and Space Museum present "Mission To Mir" filmed in space by the astronauts with the co-operation of the National Aeronautics and Space Administration (NASA). Director (Russia) Ivan Galin; Director of Photography James Neihouse; Music by Micky Erbe and Maribeth Solomon; Executive Producers Andrew Gellis and Jonathan Barker; Producers Toni Myers and Graeme Ferguson

American astronauts and Russian cosmonauts have joined forces 200 miles above the Earth as the space shuttle links with Space Station Mir. In Mission to Mir, IMAX® cameras have captured the excitement and emotion of these dramatic events which herald the next age of space exploration.

Putting aside the days of the Cold War, we go behind the scenes of the Russian space program which was, until recently, accessible only to a few. Now we can explore Star City where Russians and Americans together are preparing for upcoming missions; thrill to a thunderous Soyuz launch at Baikonur; and witness the in-orbit drama of the Mir-Shuttle rendezvous.

Lights, camera, liftoff - it's Mir, the movie: Florida Today, November 5, 1997.

"The year is 1999 and it's a sad day for Russia's space program. The Russians are turning out the lights on their beloved Mir space station and bringing home the last cosmonaut.

But wait. There's one last snag. A renegade cosmonaut insists on remaining aboard, declaring he will orbit the earth for the rest of his days. Ground controllers order him home, then plead and beg, but can't persuade the maverick spaceman to abandon ship. The last-ditch plan: Send up a woman to lure him back.

As if there hasn't been enough high drama on the Mir in recent months, Russian film director Yuri Kara is pushing to make a movie - with real actors aboard the space ship - before the Mir is discarded in about two years."

CNN's John Holliman headed for visit to Mir? Florida Today, October 29, 1997.

"The Tokyo Broadcasting System paid the Soviets $12 million to send news director Toyohiro Akiyama on an eight-day Mir mission in December 1990. He was the first, and so far only, journalist to fly in space."

SPACE ATHLETIC EVENTS

Description:

Conceived as one of the markets for future space entertainment in the CSTS Final Report, the concept is to hold regular sporting events in an on-orbit facility, with a down-link for live international television broadcast. There are unique attributes of space athletic events that may generate significant levels of interest amongst earth-based audiences. New forms of sporting events would have to be created to take advantage of the unique characteristics of microgravity, whether they be derived from existing events (e.g., space soccer) or created as entirely new sport.

Artificial-Gravity Swimming Pool, Patrick Collins, Sunao Kuwahara, Tsuyoshi Nishimura, Takashi Fukuoka, Journal of Space Technology and Science, NASDA/Hazama Corporation, 1997.

> *"One of the uses that has been proposed for fully reusable launch vehicles is "space tourism", the making of short visits to low Earth orbit by fare-paying passengers. This seems to offer the potential to generate a large commercial market, of the order of tens of launches per day, which could amortize the development cost of a new generation of reusable launch vehicles. Recently there has been a considerable increase in research concerning this possibility, with an international symposium being held in Bremen, Germany in March 1997, a session being held on the subject for the first time at the 1997 IAF Congress, the Space Transportation Association in Washington, D.C. publishing a report on it in collaboration with NASA, and the AIAA holding a workshop on the subject in January 1998, among other activities.*
>
> *Once businesses start to offer travel services to low Earth orbit, it is expected that orbiting "hotels" will be developed to enable guests to enjoy a variety of entertainment in Earth orbit. One feature of such hotels will be sports centers providing guests the opportunity to enjoy moving about freely in weightlessness, or "zero gravity". This paper considers one possible facility in such a sports center, namely a rotating, artificial-gravity swimming pool."*

Design and Construction of Zero-Gravity Gymnasium, Patrick Collins, Sunao Kuwahara, Tsuyoshi Nishimura, Takashi Fukuoka, Tokyo University/Hazama Corporation, 1997.

> *"In the future, as orbiting hotels become more sophisticated more advanced facilities will be developed. One direction of such development will be to include larger rooms for guests to experience activities in "zero gravity", as it is popularly known. The paper considers the design of a small gymnasium that might be the first of such sports centers to be built and used in orbit."*

SPACE TOURISM

Description:

In the area of human space flight, the projected markets for space tourism appear enormous, given the right circumstances (e.g., radically lower cost to orbit, enhanced safety). According to a recent study on space tourism, the total US market for travel and tourism exceeds $400 million per year. It was described by the CSTS as the largest industry in the world with economic participation by a spectrum of companies ranging from multi-national corporations to individual entrepreneurs.

Branson Boldly Goes into the Space Business: The Sunday Times, March 29, 1999.

> *"NEVER lacking ambition, British entrepreneur Richard Branson wants to extend his business empire into the stratosphere and claim space as Virgin territory. Mr. Branson will this week launch his most ambitious project yet as Virgin Galactic Airways begins its eight-year mission to make space the next tourist hotspot.*
>
> *The entrepreneur has been in negotiations with the Rotary Rocket Company, a US space-plane designer, to sell the first civil space experience. The space-plane is being designed as a reusable eight-seat craft that will provide those paying about $US 100,000 ($157,000) a trip the opportunity to experience weightlessness and view the curvature of Earth..."*

Space Adventures Inc. Offers Bookable Adventures in Space Now, Company Press Release, September, 1997.

> *"Space Adventures will offer microgravity simulation flights domestically. This organization is backed by two travel companies, Omega World Travel and Quark Expeditions. The companies' current offerings include rides on Russian MiG-25 Foxbat fighters for $12,000 per ticket and micro-gravity simulation flights in Russia at a cost of $5,500 per ticket. This organization is also taking deposits for suborbital flights.*
>
> *Do away with gravity in a zero-gravity aircraft, or climb to the outer rim of the Earth's atmosphere in a Russian MiG 25 -- two giant "Steps to Space" ™ that can be booked today with Space Adventures Inc.*
>
> *Joining forces in the new venture are Virginia-based Omega World Travel, Connecticut-based Quark Expeditions and a prestigious Advisory Board including four former astronauts."*

Spacetopia

"Spacetopia Inc has been established to exploit the emerging market for space tourism and related services in Japan. It will also participate in other commercial space activities that will arise with the sharp reduction in launch costs that space passenger travel will bring about.

Founded by partners with extensive knowledge of both the Japanese travel market and global efforts to bring space tourism services to reality, Spacetopia Inc will have three main fields of activity - travel, media, and business services.

Spacetopia is a unique gateway to Japan for non-Japanese companies looking to participate in this field - whether seeking partners, aiming to serve the Japanese market, or requiring consultancy on specific projects."

Zegrahm Space Voyages

"Zegrahm Space Voyages announces an unprecedented travel adventure once thought unattainable to the general public: a complete space experience culminating with an actual flight to space.

Zegrahm Space Voyages, a division of the Zegrahm Expeditions travel company, is taking reservations for departures that begin July through December, 2002.

Our aerospace partner has developed the vehicle technology to take you up to 100 km — official "astronaut altitude" — where weightlessness can be experienced and the Earth's curvature provides the backdrop. We've integrated this flight into a remarkable 7-day travel program that will immerse you in space exploration, just as we immerse our expedition travelers in destinations like Antarctica, Africa, the South Pacific and Madagascar."

Sharespace Foundation

The Sharespace Foundation, founded by Apollo 11 astronaut Buzz Aldrin is a "cooperative" venture where participants will contribute "as little as $10" for chance to ride into space. In joining the cooperative, each participant gets an ongoing chance to be randomly selected for training as astronauts and a ride into space on a next generation space vehicle. For those that do not make the final selection process, alternative chances are available for sub-orbital flights, zero-g flights, tours of space facilities, and attendance at domestic and international launches.

"The Sharespace Foundation has a solution to these problems that will give ordinary citizens with ordinary means the chance to fly in space, possibly before the next generation passenger flying space vehicles come into service. Sharespace seeks to create a cooperative whereby any citizen can contribute as little as $10 dollars and have the opportunity to fly in space.

Sharespace will select a pool of potential astronauts by random selection from those who choose to participate. After appropriate medical screening, these candidates will have the opportunity to train and compete for a ride into space. Those who are selected as potential astronauts, but who are not selected to fly, will nevertheless get to participate in the space program. They will receive alternative benefits, possibly including sub-orbital flights, zero-g flights, tours of space facilities, and attendance at launches in the U.S. or abroad.

Unlike a traditional random selection process, the Sharespace cooperative will allow ongoing participation. In other words, by joining with as little as a single $10 contribution, a participant would be eligible for future drawings. Furthermore, association with Sharespace would make the participant a member of a larger movement and entitled to other benefits."

Japanese Pepsi Drinkers Could Win a Trip to Space in 2001, Reuters, Wired Magazine, Yomiuri Shimbun, April 21, 1998.

"Reuters and Wired Magazine are reporting that the Japanese distributor of Pepsi, Suntory Ltd., plans to offer its customers the chance to fly in space as part of a promotional campaign. Five winners will receive the opportunity to fly into space in 2001 via Zegrahm Space Voyages, a U.S. space travel agency."

Teacher's Dream as a Pilot to be Fulfilled With Russian MiG Flight, X Prize ® Foundation Press Release, October 29, 1998.

The X Prize Foundation is promoting a contest through its affinity credit cards. A small portion of the proceeds will go to the X Prize, and the credit card customer will have his/her name automatically entered into a sweepstakes. The awards include hundreds of flights on a MiG-25 and the grand prize will be a sub-orbital flight on board one of the vehicles vying for the X Prize. The sweepstakes winners will be announced after the X Prize has been won.

"Buck, a special-education teacher from Davison, Mich., will soon travel to Moscow and up to 85,000 feet at two-and-a-half times the speed of sound aboard a Russian MiG-25 as the first winner in the YOUR TICKET TO SPACE (SM) sweepstakes. The first-of-its-kind quarterly sweepstakes is sponsored by the X Prize ® Foundation, a nonprofit organization created to jump-start the space-tourism industry."

Hotels in Space, Barron Hilton, 1967.

"The possibility of an orbiting or lunar hotel is discussed. It is suggested that when space scientists make it physically feasible to establish hotels in space and to transport people, the hotel industry will meet the challenge."

Demand for Space Tourism in America and Japan, and its Implications for Future Space Activities, P. Collins, R. Stockmans, and M. Maita, 1995.

"In 1995 market research on the potential demand for space tourism has been carried out in the USA and Canada, supported by the National Aerospace Laboratory in Japan. Although estimates have been published before, this is the first actual market research of its type to be done on the North American market. This paper describes the research, and compares the data with earlier research conducted in Japan. Although there are a number of differences in the results, they are broadly comparable to those in Japan, which suggests that space tourism services would also be very popular in North America. The paper then considers the implications of this research for future space activities and space transportation systems."

General Public Space Travel and Tourism - Volume 1 Executive Summary, NASA/ Space Transportation Association, March, 1998.

"Travel and tourism is one of the world's largest businesses. Its gross revenues exceed $400 billion per year in the U.S. alone, and it is our second largest employer.

The first professional space tourism market studies have been conducted in several countries in the past few years, especially in Japan and here. The U.S. Study makes it clear that, conceptually, tens of millions of us would like to take a trip to space if we could do so with reasonable safety, comfort and reliability, and at an acceptable price. Initial businesses will address the desires of those willing to pay a greater price and accept a greater risk."

Practical Tourism in Space, Samuel M. Coniglio, Space Tourism Consultant, 1996.

"The World Travel Tourism Council estimates that 1995 revenues for tourism worldwide was $3.4 trillion. The city of Orlando, Florida has one of the largest tourism centers in the United States, including Walt Disney World, Universal Studios, and Sea World. In a recent economic impact study, Orlando received an economic impact of $13.1 billion from theme parks, hotels, restaurants, and shopping centers.

This paper will discuss two projects which a major entertainment or tourism corporation could get involved in immediately. First, cross-industry communication can be initiated through conferences between leaders of the hotel, tourism, entertainment, aerospace and other industries. Second, the dream of recreational space travel can be brought closer to reality through a phased approach, starting with sponsorship of the X-Prize contest, by developing simulator rides and virtual reality shows based on actual space projects, and soliciting bids for constructing space cruise ships and an orbital hotel."

Report of Working Group No. 4 of the AIAA/CEAS/CASI Workshop on International Cooperation in Space: The working group on public space travel, Ivan Bekey, January, 1998.

"Mandate to recommend steps that should be taken internationally to enable and facilitate travel to and from space for the general public.

Extensive travel by air, sea and land for pleasure and business has become a commonplace fact of modern life. By contrast, travel in space is available to only a few highly trained government astronauts, and the public's perception is that it cannot be otherwise. In fact, "space tourism", routinely available to the general public at affordable prices, is much closer at hand than most people realize. It is sure to become a huge commercial space industry in the near future."

Economically Viable Public Space Travel, Ivan Bekey, 49th IAF, October 2, 1998.

"This paper presents the results of new study by the author that analyzed the potential market for Public Space Travel (PST), defined a set of optimum launch vehicles for this service, and set up a series of paper businesses to take as few as 100 and as many as 1,000,000 people into space annually. To enable the analyses, the study analyzed market surveys done to date and derived a "most likely" market elasticity model."

A Common Cost Target of Space Transportation for Space Tourism and Space Energy Development, Makato Nagatomo, Patrick Collins, ISAS/NASDA, July 18, 1997.

> *"In this paper, we have selected two commercial activities, tourism and satellite solar power stations, of which the space transportation requirements are realistically predictable in economic terms. Space tourism is considered as part of the tourism industry - a global business which has driven the development of the civilian aerospace industry since WW2, and which seems large enough to continue to support the aerospace industry in the post cold-war era. Even though the scale of space tourism activities may be much smaller than the airline industry, it is assumed that similar operating concepts will be applied to these new services. The business of satellite solar power stations considered here is to build solar power satellites in low equatorial orbits and sell microwave power to ground-based electric utility companies. The upper limit of the costs for the system will be determined by the price competition of other electricity sources."*

Artificial Gravity and the Architecture of Orbital Habitats, Theodore W. Hall, Department of Architecture, University of Hong Kong, 1997.

> *"This paper examines the rationale, requirements, limitations and implications of artificial gravity in the design of orbital habitats. Long-term exposure to weightlessness leads to a chain-reaction of undesirable physiological adaptations. There is both theoretical and experimental evidence that artificial gravity can substitute for natural gravity to maintain health in orbit. Aerospace medical scientists have conducted many studies during the past forty years to determine the comfort boundaries for artificial gravity. They express comfort in terms of centripetal acceleration, head-to-foot gravity gradient, angular velocity, tangential velocity, cross-coupled head rotations and the Coriolis effects of relative motion in rotating environments."*

Next Space Race: Tourism, Jennifer Hillner, Wired News, February 23, 1998.

> *"Almost two years after a St. Louis, Missouri, nonprofit organization offered $10 million to the first private company to take tourists into space, several serious competitors are testing their hardware and aiming for a launch window around 2001.*
>
> *"Let's not wait another 50 years before we get regular people into space," said Diane Murphy of the X Prize Foundation, which in May 1996 put up the prize to hurry along the development of commercial space flight. The foundation's $10 million purse will go to the creator of the first private reusable spaceship capable of carrying three humans 100 kilometers above the Earth on two consecutive flights within two weeks..."*

X PRIZE Foundation

"The X PRIZE was founded on 18 May 1996 in St. Louis for the specific purpose of stimulating the creation of a new generation of launch vehicles designed to carry passengers into space. Today if you are interested in flying there are only two options, the US Space Shuttle or the Russian Soyuz, and neither of these are available at a reasonable cost or on a regular basis to the general public. The problem is not the lack of financial resources among today's adventure tourists, nor the demand in the marketplace, but specifically the lack of licensed, low-cost, reliable vehicles. Taking a lesson from the history books, we modeled the X PRIZE after the early aviation prizes. Between 1905 and 1935, hundreds of aviation prizes stimulated the creation of very different aircraft designs, each of which explored different regions of flight and different mechanisms for optimizing speed, safety and low cost travel. Today the X PRIZE is doing the same. Since our inception three years ago over 16 teams have registered for the competition and we have raised over $5M towards the prize."

SPACE THEME PARK

Description:

The long-term goal of building an on-orbit facility to house and provide entertainment to visiting tourists is envisioned as a significant mass-market application for space. It is possible that terrestrial "Space Theme Parks" will pave the way as Earth-based counterparts to the eventual on-orbit facilities. The terrestrial parks will have extensive facilities to re-create the space experience on the ground. Additional revenues will be generated from licensing and merchandising tie-ins to the theme parks and government and commercial space companies.

Terrestrial space theme parks exist on a global basis today and are quite successful. They come in a variety of forms, (e.g., space-oriented museums to space research, launch and recovery centers, and space camps).

The Kennedy Space Center Visitor Complex, Florida

"The Kennedy Space Center Visitor Complex provides an exhilarating and educational experience of the space program.

Whether touring the Rocket Garden, or boarding a full-scale replica of the Space Shuttle Explorer, visitors are guaranteed to gain a new perspective on the incredible feats accomplished by the space program.

The Visitor Complex also offers amenities and services such as bus tours, restaurants, first-aid, and pet kennels. Admission to the Kennedy Space Center Visitor Complex is free; there are nominal charges for bus tours and IMAX® films.

The Kennedy Space Center Visitors Center in Florida and the Space Center Houston in Texas operate full service entertainment centers with the space "experience" mixed with tours of NASA facilities, museums and gift shops."

The National Air and Space Museum Washington, DC

The National Air and Space Museum draws over 10 million people per year.

"The Smithsonian Institution's National Air and Space Museum (NASM) maintains the largest collection of historic air and spacecraft in the world. It is also a vital center for research into the history, science, and technology of aviation and space flight. Located on the National Mall in Washington, D.C., the Museum has hundreds of artifacts on display including the original Wright 1903 Flyer, the "Spirit of St. Louis," Apollo 11 command module, and a Lunar rock sample that visitors can touch. The museum continues to develop new exhibits to examine the impact of air and space technology on science and society."

Spaceport Kansas: A Visit to the Kansas Cosmosphere and Space Center, Jeff Foust

"Hutchinson, Kansas usually doesn't make anyone's list of cities with an influential space presence. Jeff Ollenburger wants to change that.

"We are planning to become the most comprehensive space museum in the world," Ollenburger, marketing coordinator for the Kansas Cosmosphere and Space Center, said in a recent interview. "That's our goal."

While the Cosmosphere lacks the publicity of the Smithsonian's Air and Space Museum or NASA centers in Houston or Florida, it makes up for it with an impressive display of space artifacts that will soon be bolstered by a multi-million dollar expansion project which will triple the amount of display space available. By the end of the this year, when the expansion project is completed, only the Air and Space Museum will have a larger collection of space artifacts than the Cosmosphere.

The Cosmosphere, which attracted over 300,000 visitors from the U.S. and 60 other countries last year, combines its collection of American and Soviet space artifacts with an ambitious educational program that include a SpaceCamp-like summer program, the only OMNIMAX theater in the state, and the Justice Planetarium, the newest and largest planetarium in Kansas. Put together, they make the Cosmosphere the best space museum in the Midwest, and among the best in the country".

Gorky Park, Russia

The Buran shuttle ride in Moscow, Russia, was added to the variety of other attractions at the famed Gorky Park. It appears that the ride is an actual test vehicle that has been outfitted with zero-gravity simulation seats. The ride consists of a short multi-media presentation with live-action flight attendants.

EDUCATION

EDUCATION CONTENTS:

Description:

Private sector for-profit initiatives in education can be significant beneficiaries of the ISS program in two important ways. First, educational curricula can be developed based on the research conducted on-board the ISS. Secondly, on-orbit facilities may be used to generate lectures from space that may then be used as classroom material (e.g., space, earth and life sciences).

EDUCATIONAL DEVELOPMENT FROM ISS RESEARCH

Description:

Private sector education initiatives surrounding ISS research represent potential commercial markets where NASA expenditures could be reduced. For this commercial market to appear, private organizations must be willing to commit resources to enable space education based on ISS research, either through their marketing or public relations budgets.

Industry has proposed several corporate sponsorship initiatives to answer NASA's request for more industry participation in meeting its ISS education goals.

The International Space Station: An Opportunity for Industry-Sponsored Global Education, Cathleen E. Shields, The Boeing Company, 1999.

> *"In 1996, Boeing began exploring the possibility of developing an international space education program that would utilize existing space assets and then transition to the International Space Station upon assembly complete. The effort was initiated for two reasons: (1) to bring corporate money into human space utilization, and (2) to perform outreach for NASA. It was believed that the private sector would sponsor education in space if the program were creative and exciting, if the educational value was compelling, and if the sponsorship benefits were attractive and achievable. We believed that few organizations would walk away from the opportunity to bring education to the children of the Earth."*

S*T*A*R*S - Utilizing Space and Space Research for Educational Initiatives, Kimberly A. Campbell, SPACEHAB, 1999.

> *"SPACEHAB, Inc., the leading commercial space services company, along with the Center for Microgravity Automation Technology, offers an exciting educational opportunity to conduct microgravity research aboard a variety of vehicles. SPACEHAB has established a "Microgravity Staircase," a comprehensive portfolio of ground-based, sub-orbital and space-based microgravity research facilities designed to meet a variety of needs and budgets. Via the Microgravity Staircase, the S*T*A*R*S Program provides research opportunities aboard a variety of platforms to the academic community. Each step in the staircase offers a different duration of microgravity exposure, providing students and educators steadily increasing periods of microgravity. Whether a given experiment requires a 20-second ride on a parabolic aircraft, a 15-minute trip aboard a sub-orbital rocket, or a long-duration stay on an orbiting platform, SPACEHAB has the ability to provide academic opportunities and servicing before, during and after flight."*

EDUCATIONAL PROGRAMMING

Description:

The educational programming that will be generated on the ISS through a variety of sources is likely to find significant terrestrial markets. There will be global access to educational programming produced on ISS or about ISS which will be distributed through any number of channels (television, internet, radio, videotape, written classroom curriculum, live presentations, etc.). It is not clear as to whether for-profit educational organizations will be the primary generator of ISS-related educational programming, or whether these tasks will be limited to non-profit and governmental organizations only.

Corporate Sponsored Education Initiatives on Board the ISS, Ian T. Durham, Alyson S. Durham, James A. Pawelczyk, Lawrence B. Brod and Thomas F. Durham, 1999.

> *"This paper proposes the creation of a corporate sponsored "Lecture from Space" program on board the International Space Station (ISS) with funding coming from a host of new technology and marketing techniques. Astronauts in residence on board the ISS would conduct short 10 to 15 minute live presentations and/or conduct interactive discussion carried out by a teacher in the classroom. This concept is similar to a program already carried out during the Neurolab mission on Shuttle flight STS-90. Building on that concept, the interactive simulcasts would be broadcast over the Internet and linked directly to computers and televisions in classrooms worldwide. In addition to the live broadcast, educational programs and demonstrations can be recorded in space, and marketed and sold for inclusion in television programs, computer software, and other forms of media. Programs can be distributed directly into classrooms as an additional presentation supplement, as well as over the Internet or through cable and broadcast television, similar to the Canadian Discovery Channel's broadcasts of the Neurolab mission. Successful marketing and advertisement can eventually lead to the creation of an entirely new, privately run cottage industry involving the distribution and sale of educationally related material associated with the ISS that would have the potential to become truly global in scope. By targeting areas of expertise and research interest in microgravity, a large curriculum could be developed using space exploration as a unifying theme. Expansion of this concept could enhance objectives already initiated through the International Space University to include elementary and secondary school students. The ultimate goal would be to stimulate interest in space and space-related sciences in today's youth through creative educational marketing initiatives while at the same time drawing funds almost entirely from the private sector."*

U.S. SPACE CAMP

A good example of an existing space education institution that would also benefit from the creation of educational programming developed on the ISS would be the US Space Camp. Wernher von Braun founded the U.S. SPACE CAMPS to expose young people to science and math, using the space program as the focal point of a course of study. The first camp was established at the U.S. Space & Rocket Center in Huntsville, Alabama in 1982. By 1999, the U.S. SPACE CAMPS will have graduated over 300,000 "trainees".

"U.S. SPACE CAMP® is a five-day program jam-packed with astronaut training for young people. Activities include simulated Space Shuttle missions, IMAX® movies, training simulators (like the 1/6th Gravity Chair), rocket building and launches, scientific experiments, and lectures on the past, present, and future of space exploration.

We also offer programs for older students. SPACE ACADEMY® is for young people in grades 6-8 and ADVANCED SPACE ACADEMY® is for students in grades 9-12. Another popular program is Parent/Child SPACE CAMP -- a weekend of activities and missions where an adult/child pairs go through the same program together. We also have ADULT and TEACHER programs, plus CORPORATE SPACE ACADEMY, which uses shuttle missions and astronaut training to teach team building.*

SPACE CAMP has been operating since 1982. We are the largest camp operation in the United States, having graduated almost 300,000 campers. SPACE CAMP programs in Alabama are operated by the U.S. Space & Rocket Center and the Alabama Space Science Exhibit Commission. California and Florida locations are owned and operated by the U.S. Space Camp Foundation, a non-profit organization. Alabama and Florida locations are accredited by the American Camping Association, and the new California locations are in the process of accreditation."

International Space University

The ISU offers graduate level courses in comprehensive, space applications, engineering, science, management, space policy, and law. ISU currently offers three programs: the Summer Session, the Master of Space Studies, and the Professional Development Program. Its course curricula also benefit greatly from educational programming generated on the ISS.

"Many and varied practical applications, huge advances in understanding the cosmos, preparation for interplanetary exploration - these are some aspects of the progress accomplished in the utilization of space for peaceful purposes over the past forty years.

The world's space programs have become increasingly international and commercial in nature. New skills need to be developed and enhanced in order to manage the engineering, economic, political and organizational aspects of programs and space professionals of the future need a very broad base of knowledge.

At the International Space University, international experts train and educate professionals to take the lead in the international space arena.

Interdisciplinary diversity integrated into a coherent, structured whole in a truly international, multicultural environment. The originality of ISU's programs lies in this approach.

At ISU, all students study all space-related disciplines, vastly broadening their vision and enabling them to understand the complex interactions between disciplines. By approaching the utilization of space from a global perspective, ISU gives its graduates a powerful, competitive edge in the profession. They become capable of understanding and easily crossing the traditional barriers arising between individuals from different nations, with different cultural backgrounds. They break new ground in international cooperation on space programs."

The JASON Project

"What is the JASON Project? After discovering the wreck of the RMS Titanic, world-famous explorer Dr. Robert Ballard received thousands of letters from students around the world wanting to go with him on his next expedition. In order to bring the thrill of discovery to millions of students worldwide, Dr. Ballard founded the JASON Project, a year-round scientific expedition designed to excite and engage students in science and technology and to motivate and provide professional development for teachers. The JASON Project has been praised as the leader in distance learning programs, and continues to expand its reach by adding more "components" to the Project experience.

Through JASON XI, we will trace the path of ocean and space research and exploration. In the past, humans have been limited to very short visits to these extremes. The Aquarius Underwater Laboratory and the International Space Station allow humans to study oceans and space for longer time periods, and in new and exciting ways..."

ADVERTISING

ADVERTISING CONTENTS:

Description:

Advertising, as it relates to the ISS, represents a broad market category that includes the use of ISS in all areas related to sales and promotion. The international nature of the ISS and the presumed universal appeal of space will serve the advertising and marketing communities in an increasingly competitive global business environment. Advertisers will be able to use the ISS program indirectly through the licensing of ISS images and logo for advertising and merchandising or directly through on-orbit filming of commercial spots.

The domestic focus of this study dictates that we concentrate on the US advertising industry and its interest in the creation and broadcast of advertisements featuring the ISS. Historically, space programs such as Apollo and the space shuttle have been used widely in advertising and licensing tie-ins (e.g., Omega Watches). The use of Mir for on-orbit endorsements and filming of commercials has more recently proven the interest in space for a number of well-known international consumer products companies (e.g., Pepsi, Swatch).

LICENSING, MERCHANDISING, AND ENDORSEMENTS

Description:

Licensing of images and logos of the International Space Station, merchandising of ISS-related products and, celebrity-style endorsements of products and services represent potentially significant sources of commercial revenue. There are some successful recent examples of this phenomenon (e.g., Mattel Hot Wheels Mars Rover), but the full extent of the ISS-related potential is yet to be realized.

Merchandising of the t-shirt and coffee mug variety has been a staple of the gift-shop economies surrounding NASA's space flight centers for many years. The visitor centers at Kennedy Space Center in Florida and Johnson Space Center in Texas represent particularly large merchandising operations, with their respective space center tours and gift shops. While merchandising does generate large revenues for the local economies surrounding the NASA Space Centers, a variety of legislative and other constraints does not currently allow licensing fees to flow back to NASA.

Endorsement of products or services by active astronauts is currently prohibited by NASA. There are a variety of organizations that represent former astronauts as their "agents". They are able to arrange speaking engagements, presentations, autograph appearances, and product endorsements by a number of former astronauts.

NASA Imagery Usage Policy:

"1) NASA does not endorse or sponsor any commercial product, service, or activity.

2) *The use of the NASA name, initials, any NASA emblems (including the NASA Insignia, the NASA Logo and the NASA Seal) which would express or imply such endorsement or sponsorship is strictly prohibited.*

3) *Use of the NASA name or initials as an identifying symbol by organizations other than NASA (such as on foods, packaging, containers, signs, or any promotional material) is prohibited. The only exceptions are noted immediately below.*

4) *NASA does permit the use of the NASA Logo and Insignia on novelty and souvenir-type items. However, such items may be sold and manufactured only after a proposal has been submitted to and approved by a representative from the Public Services Division (202/358-1750) in accordance with 14 CFR (Code of Federal Regulations) Part 1221. NASA does not grant anyone exclusive rights to use any of the Agency identities.*

5) No approval for use is authorized by NASA when the use can be construed as an endorsement by NASA of a product, service, or activity.

6) NASA emblems should be reproduced only from original reproduction proofs, transparencies, or computer files available from NASA Headquarters. Please be advised that approval must be granted by the Public Services Division before any reproduction materials can be obtained.

7) NASA should be acknowledged as the source of its material.

8) It is unlawful to falsely claim copyright or other rights in NASA material.

9) NASA shall in no way be liable for any costs, expenses, claims or demands arising out of use of NASA's cassettes and photographs by a recipient or a recipient's distributees.

10)NASA personnel are not authorized to sign indemnity or hold harmless statements, releases from copyright infringement, or documents granting exclusive use rights."

Space Program and Entertainment Worlds to Collide at JPL, John G. Watson, Media Relations Office, Jet Propulsion Laboratory, September 19, 1998.

"Toy manufacturers, entertainment industry executives and others interested in space program licensing opportunities are invited to attend the fourth annual Toys, Games and Multimedia Workshop "Playing Among the Planets 98," a one-day seminar at NASA's Jet Propulsion Laboratory.

With the success of last year's "Hot Wheels Sojourner Mars Rover Action Pack," Mattel's toy versions of the Mars Pathfinder rover and lander, interest in working with JPL to produce space-related toys and entertainment industry products has never been higher, say workshop planners."

The Astronaut Connection

"Astronauts have accomplished and experienced the things that represent dreams and imagination to the rest of us. They are universally trusted, respected and revered. People of all

ages and backgrounds have a fascination with this group of explorers. They are American heroes. Data Matrix is proud to bring you retired Astronauts who can make commercial appearances, give dynamic presentations, participate in promotional programs or be used for corporate and product endorsements. When a retired Astronaut appears they bring the excitement of space flight and can be available to:

- *Give motivational speeches*
- *Deliver presentations to small or large groups*
- *Sign autographs and have pictures taken with attendees*
- *Be interviewed/promote their appearance in the local media*
- *Endorse companies and their products"*

SPACE ADVERTISEMENT

Description:

Space advertisement consists of either commercial product placement or on-orbit filming. Product placement describes the placement of commercial products, advertisements or corporate logos in locations where they will be visible to cameras filming other on-orbit activities. On-orbit filming consists of filming actual advertisements in or around the orbiting facility, often with the crew taking part in the spot.

Mir Cosmonauts Pitch Pens on U.S. Television, Florida Today, February 8, 1998.

> *"Two Russian cosmonauts aboard the Mir space station, appearing live on the QVC shopping channel, set out to hawk the American-made $32.75 Fisher Space Pen, used on NASA space flights since 1967 because it can write in the absence of gravity. As they orbited 200 miles above the Earth, a technical problem kept Commander Anatoly Solovyov and flight engineer Pavel Vinogradov from being heard discussing the pen. So one of them simply used it to write "QVC" on a pad.*
>
> *But the featured attraction at the sale, anchored from the Catch a Rising Star nightclub in Manhattan, was the $25,000 Sokol KV-2 spacesuit.*
>
> *Russian space chief Yuri Koptev has said previously that Mir would be used regularly as an advertising prop.*
>
> *It doesn't make any difference for us what to advertise -- cars or foodstuff. The only condition is that advertising doesn't contradict legal and ethical norms,' Koptev said."*

Russian cosmonaut films milk ad on Mir space station, Florida Today, August 21, 1997.

> *"One small drop of milk; one giant leap for TV commercials.*
>
> *When he wasn't scrambling to fix his accident-prone space station, Mir cosmonaut Vasily Tsibliyev was busy making a television commercial for an Israeli brand of long-life milk."*
>
> *The commercial - broadcast Wednesday on Israel's Channel Two television - shows Tsibliyev swallowing a floating blob of Tnuva milk..."*

NASA Watch Website:

Draft Partner Program Directive concerning the proposed ISS external graphic markings:

July 1999

T. W. Holloway, Manager

International Space Station Program

TO: Distribution

SUBJECT: International Space Station Program Guidelines for Graphic Markings on International Space Station Elements, Systems and Payloads

OFFICE OF PRIMARY RESPONSIBILITY: International Space Station Program Office

1.0 SCOPE AND OBJECTIVES

The participating parties to the International Space Station (ISS) Program have determined it to be in the best interests of the Program to ensure that all external graphic markings on ISS elements, systems and payloads shall be simple, professional, effective for identification, and, to the extent practical, standardized. Thus, notwithstanding the fact that each partner has its own internal standards and regulations, the guidelines set out below constitute a common set of agreed guidelines for external graphic markings on all ISS elements, systems and payloads.

These guidelines apply to graphic markings which are visible on the exterior of the ISS. These guidelines are applicable to ISS elements, systems, payloads and logistics resupply articles (for example, spares, maintenance items and consumables for ISS use). These guidelines do not cover graphic markings on the interior of the ISS or markings on ISS crew attire.

Each partner using its own space transportation system (expendable or reusable, launch vehicle or orbital transfer vehicle) to provide launch and or return transportation services for the ISS shall determine the graphic markings on their transportation systems.

For purposes of these guidelines, the provider of an element is the country/agency provider of record set out in the ISS Intergovernmental Agreement. For example, the United States/NASA is the provider of the Multipurpose -Pressurized Logistics Module, the FGB, the Centrifuge Accommodation Module and Nodes 2 and 3, notwithstanding the fact that these items were developed by other partners and participants. Similarly, the provider of a payload is the country/agency including the payload in its Partner Utilization Plan.

2.0 GUIDELINES FOR GRAPHIC MARKINGS ON ISS ELEMENTS, SYSTEMS AND PAYLOADS

A. Types of Markings

Each element, system and payload of the ISS may carry the providing partner's national colors, the name of the providing country, the name given the element, and the insignia of that partner's cooperating agency, and in the case of Japan, that partner's assisting agency -National Space Development Agency of Japan (NASDA).

B. Size and Location of Markings

The size and locations of the graphics area will be limited by applicable technical constraints as determined by the ISS Partner Program Managers and in no way interfere with the integrity of orbital debris shielding, or the environment for ISS operations, such as, thermal limits, Extravehicular Activity (EVA) hand rails, EVA and other markings etc.

C. Process for Approval of Markings

In order to facilitate timely compliance with these guidelines, each of the partners shall make known their plans and intentions for marking their elements, systems and payloads. The ISS Partner Program Managers, in the Space Station Control Board (SSCB) forum, with the support of the ISS Partners Public Affairs Office (PAO) Working Group, shall review each proposed marking to confirm its compliance with these guidelines. This review shall occur at least ten months prior to launch to assure that the markings may be finalized and affixed to the flight article no later than eight months prior to launch.

D. European Space Agency (ESA) Requirements

ESA shall be responsible for identifying the graphic markings for European elements, systems and payloads on behalf of its member states.

E. Participant Countries

In case of participant countries (e.g. Italy and Brazil), the partner country through which they participate shall coordinate and approve the graphic markings in conformance with these guidelines.

F. Receipt from Another Entity

In the event that a partner receives one of its elements, systems, payloads or other ISS component from another entity (for example, through a cooperative, barter or offset arrangement), the providing partner (as defined in section 1.0 above), shall determine, following consultation with the other entity, which country or agency markings shall appear on the hardware, in accordance with its internal procedures.

G. ISS Payloads

ISS payloads may display markings, in addition to those of their providers. No markings shall be approved if they interfere in any way with the mission.

3.0 MATERIALS STANDARDS FOR GRAPHIC MARKINGS

In order to avoid generation of orbital debris from unstable graphic markings on ISS systems, elements and payloads and visiting space transportation systems, the partners shall agree on materials standards for ISS graphic markings. These materials standards shall be documented in Space Station Program Document SSP 30233, "Space Station Requirements for Materials and Processes," under the control of the SSCB.

4.0 RESPONSIBILITY

A. The ISS Partner Program Managers, in the SSC13 forum, shall approve these guidelines and any additional guidelines required for ISS-related graphic markings. The ISS Partners Public Affairs PAO Working Group shall provide expert advice and recommendations. The ISS Partner Program Managers, with the support of the ISS PAO Working Group, shall review proposed markings to confirm compliance with the guidelines and shall be responsible for considering and granting waivers when appropriate.

B. Each partner shall be responsible for any internal coordination with its agency management, government or contractors.

C. Each partner shall be responsible for ensuring its elements, systems, payloads and space transportation systems comply with these guidelines.

D. All costs associated with the design, fabrication or application of markings shall be borne by the country/agency proposing the markings unless otherwise agreed as part of a cooperative arrangement.

5.0 REFERENCES

The following references are applicable to each individual agency, respectively.

A. NASA:

NASA Policy Directive 8610.6D: "Graphic Markings on Space Transportation Vehicles, U.S. Components of the International Space Station Component Systems, and Payloads."

NASA Policy Directive 87 10, "NASA Policy for Limiting Orbital Debris Generation."

Agency Graphics Standards as authorized by Headquarters Office of Public Affairs-

(1) NASA Insignia Graphics Standards, NP-212. (2) Graphic Standards Manual (Shuttle and Spaceflight Markings).

JSC-SE-R-006, "NASA JSC Requirements for Materials and Processes."

MSFC-STD-506, "Standard Materials and Processes Control.

B. RSA:

Government Standard

C. NASDA:

NASDA Internal Regulation Concerning "NASDA" Logo

BBD-000 157 Basic Design Manual of "NASDA" Logo

JAX-99058 Basic Design Manual of "KIBO" Logo

D. ESA:

ESA Corporate Identity Guide (May 1997)

ESA/ADMIN (98) 35, "ESA Corporate Visual Identity"

E. CSA:

Government of Canada Federal Identify Program

CSA Corporate Identity Policy

6.0 WAIVERS

On a case-by-case basis, the ISS Partner Program Managers may consider partner requests for waivers to these guidelines. If, after review and discussion of the proposed deviation, through the appropriate internal partner processes, the ISS Partner Program Managers determine the markings to be acceptable and/or in the best interest of the Program, they may grant a waiver. Markings already completed on the "Unity," "Zarya" and Space Station Remote Manipulator System and Mobile Remote Servicer Base System elements, are consistent with these guidelines and were exempt from this approval process.

VII. AMENDMENT

The SSCB shall consider amendments to these guidelines upon the written request of any partner or participant.

Approvals
Alain Dubeau Date
Program Manager
Canadian Space Station Program
Canadian Space Agency
Frank A. Longhurst Date
Head, Manned Spaceflight Department
European Space Agency
Hideo Takamatsu Date
Manager, Space Station Program
National Space Development Agency of Japan
Boris D. Ostroumov Date
Deputy Director General
Russian Space Agency

APPENDIX C: METHODOLOGY

The methodology used for conducting this study was derived from the Congressional mandates of the 1998 Space Act, requirements from the statement of work, standard KPMG methodology, and suggestions adopted by KPMG based on meetings held with NASA during the study. Based on NASA recommendations, the Commercial Space Transportation Study (CSTS) was used as a framework from which to organize the focus of the research effort. The documentation collected focused on the topics of space technologies research, commercial microgravity or space-based research, non-space related industry information, and space-related literature of various types published from 1995 to present.

Materials initially provided by NASA were first reviewed for purposes of learning the overall history of the ISS program, microgravity research and NASA commercialization activities. Additional sources of documentation included:

- Federal government agencies
- State government agencies
- Industry associations
- Universities
- Private companies
- And individual space enthusiasts

During the course of the study, KPMG utilized an expert advisory panel, the CSVAT. The CSVAT met with the KPMG ISS Commercialization Study project team in Washington, D.C. on three occasions during the course of the study. The initial meeting was to get guidance and feedback on the format and direction of the study. The second meeting focused on discussions regarding preliminary findings, potential pathfinder projects, and a review of the market research reviewed up to that point. The third and final meeting was to discuss the final draft and resolve any outstanding issues.

KPMG would like to note that NASA HQ was not represented at these meetings, based upon our mutual agreement with NASA that their presence might limit the willingness of the CSVAT members to speak frankly about their views on the various topics under review. As a result, the meetings provided an excellent forum for open and honest discussion amongst the members of the CSVAT and KPMG regarding opportunities for commercialization as well as critical impediments, which hinder NASA and industry from realizing the goal of commercial utilization of the ISS.

APPENDIX D: PATHFINDERS

As discussed in the main report, during the course of the development of the market review for the International Space Station, KPMG found a range of significant impediments or barriers that must be overcome for commercial development of the ISS to flourish. In collaboration with the CSVAT, KPMG has identified a series of "Pathfinder" programs that could help to foster commercialization and commercial development by pushing the bounds which currently define the ISS operational environment. It is important to note that by the very nature of the CSVAT's composition, with representation from many of the leading aerospace companies in the U.S., that the Pathfinders presented have a correlation to their existing businesses. However, KPMG and the CSVAT want to stress that the Pathfinders we have identified are not in any way to be construed as the only opportunities available for fostering commercial activity. We highly encourage NASA to undertake a forceful proactive effort to promote the development and submission of a wide range of such opportunities by the commercial community. The Pathfinders we have included were based primarily upon their potential to accomplish one or more of the following:

- Cost Reduction – providing a significant cost savings in the area of operations or hardware procurement, by selecting privately-built hardware in lieu of the traditional NASA-driven procurement program or by allowing private industry to make use of excess capacity in the ISS/STS system;
- Capability Enhancement – improving the overall suite of services and functions available to both NASA and commercial users of the ISS by permitting additional facilities or capabilities to be added to the ISS and/or STS;
- Value Extraction – creating new streams of revenue by capitalizing on the inherent value of the ISS program, using such vehicles as licensing, sponsorship, advertising, or similar entertainment-related ventures.

The Pathfinders presented in this section represent a sample of the wide spectrum of programs and ideas that should be embraced by NASA and enabled, where necessary, by Congress in order to foster an environment that is more conducive to true commercial operation and utilization than currently exists.

PATHFINDER: INCREASE SPACE SHUTTLE FLIGHT RATE FOR COMMERCIAL MISSIONS

Description

The current flight rate for the space shuttle fleet underutilizes the capacity of the system and could be increased in order to allow additional flights to be conducted at marginal cost. These additional flights could be had without requiring an expansion of the major cost elements associated with shuttle operations (e.g., the contractor and civil service communities). The marginal cost, as well as additional costs associated with payload carrier leases, payload element support and mission integration could be borne by private sector customers.

Commercial Opportunity

By operating additional shuttle flights at marginal cost it would be possible for NASA to accelerate market demand development for space research and development by providing scheduled, accessible, repeatable flights for potential industry users. Such flights would be a critical enabler of market growth, by providing a greater set of R&D opportunities for industry to better understand the potential applications and opportunities that would be available on the International Space Station.

Advantages to NASA/ISS Commercialization

By tapping the unused flight capacity of the space shuttle, NASA would be able to foster demand and develop an understanding of price elasticity for industry use of STS/ISSresources and capabilities for space R&D. By doing so, NASA would be able to mitigateone of the most serious impediments to fostering industry demand for ISS facilities - the lack of a large database of commercially oriented in space R&D testing. The addition ofmultiple R&D related flights per year could add from two to three flights per year, thereby significantly increasing commercial access to space and stimulating industrial use of the ISS as a multipurpose R&D facility.

PATHFINDER: SPACE TECHNOLOGY TESTBED

Description

The International Space Station can be a powerful tool to satisfy industry needs for a commercial spacecraft technology testbed. A significant and growing commercial market already exists for new, more capable communications and remote sensing satellites. Competition in this market strongly motivates satellite manufacturers and spacecraft component developers to test and demonstrate new space hardware (e.g., antennas, solar panels, sensors, etc.) in a realistic environment. External attach points on the ISS allow it to function uniquely as a space technology testbed (STT) for proposed new spacecraft hardware. Commercial STT activities on the ISS encompass engineering research and technology demonstrations as well as generation of revenue by certain types of prototype hardware (e.g., advanced sensors).

In the past, the spacecraft technology demonstration function has been primarily performed by free flying satellites, typically paid for by government. However, in view of the expanding commercial satellite market, government is significantly reducing its STT activities and expecting industry to fill the gap. As a result, industry will be pushed to find an affordable alternative for conducting key space based experiments and validations. Commercial STT operations on ISS provide that alternative.

As a platform for SST operations, the ISS offers technology developers more than just the micro-gravity environment. The ISS delivers the combined environments of vacuum, micro-gravity, thermal cycling, sunlight, and earth vantage point necessary to test and verify satellite components and technologies. Additionally, ISS technology development experimenters will have a virtual presence throughout the course of a demonstration, with the possibility of retrieving their hardware for post test evaluation. Moreover, the cost of commercial STT operations on the ISS will be significantly less than that of the alternative, stand-alone technology demonstration satellites.

Commercial Opportunity

The economic sector that will initially drive this commercial use of the ISS is the multibillion dollar commercial satellite manufacturing industry. Space infrastructure revenues have quadrupled in the last ten years, and double digit percent growth is expected to continue in the future. Today the market for commercial satellite manufacturing can be segmented into GEO, Broadband LEO (internet in the sky), Big LEO (global telephony), Remote Sensing and Little LEO (messaging). The projections for commercial revenues for satellite manufacturing for the year 2000 total $7-10 billion dollars for all of these

segments. Eventually, an even larger market for satellite hardware and technology associated with space based entertainment, tourism, and manufacturing will emerge. For the current commercial satellite industry, a space technology testbed operating on the ISS can tap a potential market of $30-120 million per year. This estimate of the addressable market is based on projections from current practices and trends; it does not consider the additional potential of the ISS to expand the market or accelerate the rate of technological advancement.

Advantages to NASA/ISS Commercialization

NASA and DOD can also take advantage of this ISS based technology advancement infrastructure. They can employ the commercial STT on the ISS to engineer and test space hardware for their unique applications. Once a commercial STT on ISS demonstrates utility and ease of use to bona fide industry customers, the business concept will evolve to pay financial dividends to NASA. In the pathfinder stage, customers will pay for experiment hardware development and integration services. In the fully developed stage, customers could reimburse NASA for transportation charges and eventually pay rents for accommodations on ISS.

PATHFINDER: COMMERCIAL FREE FLYER

Description

One concept for commercialization would be to provide a long flight duration free-flyer service on a commercial basis for use with the Space Shuttle and International Space Station. A current example of this technology has been proposed. Three uses are known today – test flights for the US Air Force and commercial satellite instruments, space science missions for space agencies, and use with the ISS. Options under consideration for the free-flyer's development include the evolution of existing design or a clean sheet design. Integration services will be packaged with the flight hardware to provide an end-to-end service on a fixed-price basis.

Commercial Opportunity

Four general customer groups are known today for a commercial free-flyer service. Very preliminary discussions between industry and the US Air Force have revealed the possible need for an end-to-end, commercially provided free-flyer service for long duration flight opportunities. Space agency space science missions are flown on an irregular basis on existing and planned free-flying government carriers. A market is developing for the flight test of satellite components to shorten time-to-market for new capabilities and potentially reduce overall development cost. The ISS Program has had preliminary discussions toward the pre-planned product development of a free-flyer for Station use. Similar services on the Space Shuttle for pressurized and unpressurized research payloads and space station resupply cargo have already been proven. The addition of a robust free-flyer flight platform will address the space science and test flight objectives of space agencies, the Air Force, and the commercial satellite industry.

An existing organization has agreed to invest private capital to acquire the new spacecraft if NASA accepts the proposed Pathfinder. Three obvious development options include the evolution of the Wake Shield Facility which a private company is in the process of licensing from the University of Houston, the evolution of another existing design, or if justified by market conditions, the development of a new carrier using existing components provided on an international basis. Evolution of an existing design can minimize the development risk. Incorporation of a pallet as the free-flyer's bus will reduce system cost and expand manifesting opportunities with unrelated cargo and research missions. Joint development with the Goddard Space Flight Center of a commercial Spartan 400 could present the best scenario.

Advantages to NASA/ISS Commercialization

This commercial approach would facilitate the continued evolution of the successful Spartan spacecraft series at a fraction of the cost customers would expect to pay for a government development. NASA's mission costs would be reduced by commercial sale on each flight. Commercial practices should speed the development of the facility, making it available sooner to support the domestic satellite industry. NASA would also save funds by commercializing "routine" spaceflight operations so that it can focus on its exploration and technology development missions.

PATHFINDER: MPLM CARGO RACK PROCESSING SERVICES

Description

The proposed effort will provide NASA with Level 4 logistics services for pressurized supplies and equipment to be transported to the International Space Station (ISS) by a Multi-purpose Pressurized Logistics Module (MPLM) in Collapsible Transport Bags (CTBs). The service will deliver to NASA bagged cargo integrated into commercial logistics racks, enabling NASA and other ISS users to take advantage of commercial cargo processing services and gain use of commercially developed logistics racks. Since the commercial logistics racks are optimized for carrying logistics in Collapsible Transport Bags (CTBs), the tare weight for carrying bagged cargo is minimized. A weight savings on the order of a thousand pounds on a typical MPLM flight can be converted to additional payload. The core structure of the commercial logistics racks and the cargo processing infrastructure to support it are being developed to serve a proposed commercial logistics double module. Using the existing commercially owned hardware and processes will enable efficient commercial processing of cargo for MPLM resupply flights.

Commercial Opportunity

Use of the logistics processing service will relieve NASA of the need to develop, qualify, purchase and sustain a system optimized to carry CTBs, estimated at about a $3M effort. NASA will also gain the efficiencies of having the same logistics processing services for both of its major carriers. Commercial practices will be used in processing the logistics for the commercial logistics racks. These processes were proven in the ISS Phase I Program and are being used on ISS missions 2A.1 and 2A.2. Use of these existing processes for MPLM cargo effectively commercializes all of the ISS bagged cargo processing activities which should ultimately result in lower costs to NASA.

Commercial logistics racks will carry five more bags and 140 more pounds of cargo than NASA's Resupply Stowage Rack while weighing 263 pounds less. It will hold 465 pounds more cargo per rack in the same volume as NASA's Resupply Stowage Platform, and/or save 100 pounds of weight per rack over the (yet to be developed) Resupply Stowage Platform-2. On a typical MPLM flight with 6 to 8 bag-carrying racks, this savings results in significantly more payload carrying capacity. These margins should prove important, and may prove critical, to meeting the logistics needs of the ISS.

When a commercial customer base develops, the company should be in a position to buy from NASA an allocation of the MPLM capacity at a price which the market will support then resell it to commercial customers in conjunction with its logistics processing services.

Advantages to NASA/ISS Commercialization

This Pathfinder supports the effort by private enterprise to build a business supplying logistics service to the commercial users of the ISS. In addition, the ISS international cooperative agreements do not include transportation to ISS as part of their barter. Thus, both would likely be better enabled through the implementation of this Pathfinder. And, as ISS commercialization proceeds, there will likely be a need to transport increasing amounts of commercial utilization hardware in support of private research. Early commercialization of the logistics processing will provide a mature, market priced service for commercial customers.

	NASA'S RESUPPLY STOWAGE RACK	NASA'S RESUPPLY STOWAGE PALLET	COMMERCIAL LOGISTICS RACK
VOLUME (BAGS)	20	10	25
WEIGHT (LB)			
TARE	550	300	287
PAYLOAD	700	350	840
TOTAL	1,250	650	1,115
EFFICIENCY	56%	54%	75%

PATHFINDER: SPACECAM

Description

An existing company has expressed a desire to license the existing NASA AERCam technology to develop a commercial multi-use free flying camera system to meet ISS requirements. Use of this technology by the private entity would not incur any additional NASA engineering, construction or operations cost above what has already been spent on the technology to date.

Commercial Opportunity

Public interest in the space program is on the rise, with recent successes in both manned and unmanned projects building a heightened level of awareness and support for space-related endeavors. The SpaceCam would potentially enable the generation of significant revenue from the ISS assembly program as well as through the licensing of imagery/logos on the cameras and potentially on the ISS. Specific market opportunities for the SpaceCams include:

- Commercially produced and distributed TV programming on ISS construction & operations.
- System lease / rental for productions (TV shows, commercials, etc.)
- Sponsorship & promotional fees.
- Specialty stereo video feeds to attractions and theme parks for VR astronaut EVA experiences.
- ISS and Earth imagery sales (specialized cable networks, etc.)

Advantages to NASA/ISS Commercialization

The SpaceCam provides NASA with a proven safe, high-performance system that can be cost-effectively developed and operated. Used in close cooperation with safety and operational elements of NASA, the SpaceCam can achieve a useful, safe and minimally invasive operational system. The SpaceCam provides NASA with a significant reduction in the amount of EVA required to maintain the International Space Station. An added benefit is that it would potentially increase the efficiency of remaining EVA. The SpaceCam can increase the safety of docking / berthing operations by providing orthogonal views to assist the RMS operator. The SpaceCam provides a relatively small-scale Pathfinder for NASA to begin with. It also enhances other potential commercial opportunities by making high quality imagery of ISS exterior available, thus helping to tell the story of the ISS to the public in an appealing way and maintaining the link between the public and the ISS program as it moves forward.

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http://liftoff.msfc.nasa.gov/academy/tether/tethers.html
Tethers Unlimited Inc.
http://www.tethers.com/
TiPS Tether Physics and Survivability Experiment
http://hyperspace.nrl.navy.mil/TiPS/
The Nextwave On-Line Science Magazine
http://nextwave.sciencemag.org/
Science Magazine On-Line
http://www.sciencemag.org/
the American Association for the Advancement of Science
http://www.aaas.org/
The Institute of Electrical and Electronics Engineers, Inc.
http://www.ieeeusa.org
Applied Space Resources
http://www.appliedspace.com/
The Rand Corporation
http://www.rand.org
Design News On-Line
http://www.manufacturing.net/magazine/dn/

APPENDIX F: CSVAT LETTER OF SUPPORT

November, 1999

Mr. Mark L. Uhran
Manager, Space Station Utilization Planning
NASA, CODE US
Washington, DC 20546-0001

Dear Mr. Uhran:

"We, the members of the CSVAT, at the behest of Congress, NASA and KPMG have guided, reviewed and analyzed the 'NASA: Commerce and the International Space Station' Final Report as developed by KPMG. We have reviewed the various market research data presented, identified the most significant impediments and corresponding mitigations to commercial space development, and put forth what we consider to be potential 'Pathfinders' that could lead to near-term commercial utilization of ISS. It is our sincere hope that our thoughts and guidance on the creation of this report will advance the cause of commercial human space flight. While individual members of the CSVAT may not agree completely with all conclusions and recommendations in this report, as a Team we feel it reflects the ongoing guidance and feedback provided to KPMG."

Mr. Robert Walker,
CSVAT Chairman
The Wexler Group

Dr. David Boyle
Commercial Space Center for Engineering

Dr. Robert Dean
United Space Alliance

Mr. Frank DiBello
SpaceVest

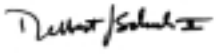
Dr. Robert Gussin
Johnson & Johnson

Dr. Shelley Harrison
SPACEHAB

Mr. Charles Lauer
Pioneer Rocketplane

Mr. Richard Smithies
Barclays Capital

Mr. Jerry Rising
VentureStar LLC



Mr. Del Schuh
Aerospace States Association

CSVAT BIOGRAPHIES

Congressman Robert Walker, President, The Wexler Group

As a former Congressman, Chairman of the House Science Committee and long-time member of the House Republican leadership, Mr. Walker provides unparalleled insight and strategic counsel on global and national issues and his involvement in a broad range of policy activities gives him a particularly unique perspective.

As Chairman of the Science Committee he was a leading advocate for research and development, dealt closely with environmental and energy issues, promoted high technology initiatives for economic growth, and advanced the nation's space program, especially the whole arena of commercial space. His space leadership made him the first sitting House Member to be awarded NASA's highest honor, the Distinguished Service Medal. In addition to his role at Wexler, Mr. Walker serves on the Board of Trustees of the Aerospace Corporation, and the Board of Directors of DCH Technology, the United States Space Foundation and the Susquehana Center for Public Policy.

Dr. David Boyle, Director, Commercial Space Center for Engineering

Dr. Boyle is the Director of the NASA Commercial Space Center for Engineering (CSCE) established at Texas A&M University. At the CSCE Dr. Boyle works with commercial partners to utilize NASA microgravity research assets such as the ISS. Prior to inaugurating the CSCE, Dr. Boyle served for five years as Deputy Director of the Center for Space Power, a NASA CSC also located at Texas A&M. In 1993, Dr. Boyle retired from 20 years active duty as a USAF officer.

Dr. Robert Dean, Vice President Strategic Planning and Business Development, United Space Alliance

Prior to joining USA, Dr. Dean was senior vice president and a member of the executive committee in charge of Advanced Business Development and Administration for Ball Aerospace & Technologies Corp. He was responsible for strategic planning, mergers and acquisitions, and international business development, and also supervised the corporation's departments of information management, human resources, public affairs, Washington, D.C. operations, facilities, and security departments.

Earlier, Dr. Dean served as general manager of Ball Space & Systems Engineering Division, responsible

for a full range of design, manufacturing, and integration skills to deliver spacecraft products & services. The Division also provided systems engineering and software-based services to federal and state agencies, prime contractors and commercial customers.

Dr. Dean held a number of senior government positions. They included Special Assistant to the President and senior Director of the National Security Council. Prior to that, he was Senior Representative for Strategic Technology Policy at the Department of State, where he held the Personal Rank of Ambassador. Earlier, he served as Deputy Assistant Secretary of State for Politico-Military affairs at the Department of State, and as National Intelligence Officer at the Central Intelligence Agency.

Dr. Dean also served as a senior vice president at Mesa Corporation and was a senior staff member at the Rand Corporation. Dr. Dean serves on a number of not for profit boards, and is a member of the Council on Foreign Relations.

Mr. Frank DiBello, General Partner, SpaceVest

Mr. DiBello is Vice Chairman and a Managing Director of SpaceVest. Previously, Mr. DiBello was the founder and managing partner of KPMG LLP's Commercial Space and Advanced Technologies Practice. He conceived and implemented this specialized consulting practice focused on the strategic development and financing of businesses applying advanced technologies to space and telecommunications. Mr. DiBello conducted comprehensive reviews of the global market competitiveness and strategic direction of major U.S. and European aerospace companies. He also had responsibility for overseeing a national outreach program to support NASA's mission of stimulating industrial interest in space-related research and development. Mr. DiBello participated in numerous strategic, financial, and market assessments in various emerging markets, such as remote sensing, data services for emerging commercial industries, launch vehicles, small satellites, and telecommunications.

In 1985, Mr. DiBello received the Medal for Distinguished Public Service, the Defense Department's highest civilian honor, for his work as President of the United Services Organization. He was also founder of the Space Business Roundtable in Washington, D.C. Mr. DiBello has taught at the Defense Systems Management College.

Dr. Robert Z. Gussin, Corporate Vice President Science and Technology, Johnson & Johnson

Dr. Gussin is the Corporate Vice President of Science & Technology at Johnson & Johnson. He joined the Corporation in 1974 as Executive Director of Research at McNeil Laboratories. During his 12 years at

McNeil, Dr. Gussin's responsibilities broadened – ultimately being promoted to the position of Vice President of Scientific Affairs. He moved to Corporate Headquarters in 1986, assuming his current role as the Chief Technical Officer of Johnson & Johnson.

Dr. Gussin has authored a number of scientific publications, as well as several chapters in academic textbooks. He is currently the Chairman of the Advisory Board of the Center for Advanced Biotechnology & Medicine at Rutgers/UMDNJ. He works with NASA on the Advisory Committee for the International Space Station, and in that capacity chairs the Committee on Commercialization. Dr. Gussin is the current chairman of the board of the Academy Industry Program at the National Academy of Science and sits on the Advisory Boards of both the Pharmacy School at the University of Florida and the Science University of Philadelphia (formerly Philadelphia College of Pharmacy & Science). He is on the Board of Directors of the Alliance for Aging Research, and chairs the Steering Committee for the Pharmacology Department at the University of Michigan. He serves on the Visiting Committee for the Harvard School of Public Health. Dr. Gussin is also a member of several professional societies, including the American Society for Pharmacology and Experimental Therapeutics, The American Society for Clinical Pharmacology and Therapeutics, the American Society of Nephrology, as well as others. Dr. Gussin also holds adjunct professorships at Michigan State University, as well as the University of Utah.

After earning a B.S. in Pharmacy and an M.S. in Pharmacology at Duquesne University, Dr. Gussin received a Ph.D. in Pharmacology from the University of Michigan. Subsequent to completing a post-doctoral fellowship at the State University of New York's Upstate Medical Center in Syracuse, Dr. Gussin joined Lederle Laboratories in 1967 where he was promoted to Director of Cardio-Renal Therapeutics in 1973. In 1995, Duquesne University presented Dr. Gussin with an honorary Doctor of Science degree.

Dr. Shelley Harrison, CEO and Chairman of the Board, SPACEHAB Inc.

Dr. Harrison has served as the Company's Chief Executive Officer since April 1996, Chairman of the Board of Directors since August 1993 and has been a member of the Company's Board of Directors since 1987. Dr. Harrison was a Member of the technical staff at Bell Telephone Laboratories and a Professor of Electrical Sciences at the State University of New York at Stony Brook. In 1973, Dr. Harrison co-founded Symbol Technologies Inc., the world's leading provider of bar-code laser scanners and portable terminals, where he served as Chairman and Chief Executive Officer until 1982. As President of Harrison Enterprises from 1982 to 1986, he managed venture financings and technology start-ups. Since 1987, Dr. Harrison has been a managing general partner of a high technology venture capital fund, Poly Ventures, L.P. ("Poly Ventures"). Dr. Harrison is also a director of NetManage, Inc., Asymetrix Learning

Systems, Inc., Globecomm Systems, Inc., AppliedTheory Communications, Inc., and several privately held technology portfolio companies.

Mr. Charles Lauer, Vice President Business Development, Pioneer Rocketplane

Mr. Lauer is a partner in Orbital Properties, LLC, as well as a co-founder and Vice President of Business Development for Pioneer Rocketplane. He is also a successful real-estate developer, and the President of Peregrine Properties in Ann Harbor, Michigan. In that capacity, Lauer has been responsible for negotiating, obtaining regulatory approvals and arranging financing for over $100 million in successful real estate development projects. While earning his income from Earth-based business deals, he has spent over a decade researching potential business opportunities in space and was an advisor and contributor in this area to the 1994 NASA/aerospace industry Commercial Space Transportation Study. In August 1995, Lauer's design for a privately funded Space Business Park was featured on the front page of the industry weekly Space News, as well as that of the March 1996 issue of Ad Astra. Mr. Lauer has been a consultant to Boeing and NASA on commercial space station development, a participant in the NASA New Space Industries Workshops, and is a member of the Board of Directors of the Space Transportation Association's Space Travel & Tourism Division. Mr. Lauer is a graduate of the University of Michigan College of Architecture & Planning.

Mr. Jerry Rising, President, VentureStar LLC

Mr. Rising is Vice President/Program Manager of the X-33/RLV Program. He led the team to develop Lockheed Martin's innovative X-33 design concept and win the X-33 Advanced Technology Demonstrator program. The X-33 is a prototype of the VentureStar Single Stage to Orbit Reusable Launch Vehicle system and it's development and flight test will validate the technology required to achieve VentureStar. Mr. Rising is responsible for overall technical and financial performance of the multi-corporation Lockheed Martin X-33/RLV team.

Mr. Del Schuh, Executive Director, Aerospace States Association

After 26 years in the aerospace and nuclear industries, Mr. Schuh accepted a position as a Project Administrator for the Corporation for Science and Technology (CST), a Quasi-governmental agency focused on economic development and technology assistance. In that capacity, he was responsible for administration of advanced technology research and development projects funded with state dollars. While at CST, he held positions of Director, Project Administration, Vice President, and then was

appointed President of the legislatively re-organized Indiana Business Modernization and Technology Corporation (BMT) (formerly CST). In that capacity, Mr. Schuh is currently responsible for all small and medium-sized business assistance operations statewide and administration of a $10 million annual budget.

In 1999, Mr. Schuh was appointed as Executive Director of the Aerospace States Association (ASA) and in that capacity is responsible for all functions of the Association. The Association is the nation's only aerospace advocacy organization with direct ties to the executive branch of state government as each state delegate is a governor's-appointee. With over 40 states participating, ASA disburses grant funds to member states for aerospace educational activities, advocates for growth and development of America's aerospace industry, and works closely with federal agencies to enhance the state/federal technology dialogue.

Also in 1999, Mr. Schuh was elected to chair the Science and Technology Council of the States (STCS). STCS membership comprises the science and technology champions from each of the 50 states and three territories. The Council works closely with the State Science and Technology Institute to assist federal agencies in understanding and working with state technology initiatives.

Mr. Richard Smithies, Director, Barclays Capital

Mr. Smithies heads up Barclays Bank's specialist Satellite & Space Industry Group. He has substantial experience in advising and financing corporations within the space industry, including the raising of over $2 billion in syndicated non-recourse loans and high yield bond financing for the global mobile satellite telephony company, Iridium. Current roles include advisory, debt and equity engagements within the launch, remote sensing and DTH industries. He also has responsibility for Barclays' own equity investment in SpaceVest, the only venture capital fund dedicated to investing in the space industry and for Barclays' well-known space and satellite stock index, SATIN, which is published on Bloomberg and distributed widely to individuals within the space community. Mr. Smithies was a member of the Barclays team named by Global Finance magazine in September 1996 as its North America Telecommunications Superstar Team. He has appeared in programs by the BBC and CBS, was on the advisory board of a space industry magazine produced by a well-known publishing house, and has been quoted in articles by Fortune magazine and regularly in industry papers. Before taking up his current position, Mr. Smithies had previously worked in several European countries and in Africa. He has a British BS degree in engineering, is a Chartered Banker and speaks several languages. He is a regular speaker at space industry conferences both in the USA and overseas.

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